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THE RELATION OF CERTAIN NON-LEGUMINOUS PLANTS TO THE NITRATE CONTENT OF SOILS.

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WE have already shown [1] that at least certain of the Leguminosæ have a distinct effect upon the process of nitrification in the soils in which they grow. Their beneficial influence on nitrification may be connected with the symbiotic relation they bear to nitrogen fixing bacteria. It is conceivable that the root tubercles with their abundant supply of nitrogenous matter may by their decay, even during the life of the plant, so increase the supply of easily decomposable nitrogenous matter in the soil as to account for the increased nitrifying power of legume bearing soils. If this be the explanation for the phenomenon it marks a sharp line in the relation of legumes toward the soil in distinction from non-legumes.

Experiments that we are conducting with cereals and with other non-legumes indicate that these crops differ one from another in their relation to the occurrence of nitrates in the soil on which they grow. The nitrate content of the soil is largely dependent on the kind of crop grown. The extensive literature

[1] Journal of Industrial and Engineering Chemistry (1910), ii, 313-315.

bearing on the nitrate content of soils contains a number of instances illustrating this relationship between the soil and the crop growing on it, but in no case has any particular significance been attached to it.

Deherain [2] found a greater loss of nitrates from the soils growing peas and clover than from those with grain crops in the drainage of the soil tanks at Grignon. He accounts for this through the inability of the legumes to take up nitrates as readily as do the graminaceous plants.

Webbel [3] took soils from fields in which the character of the soil was similar, but in which the crops were different. These were placed in lysimeters. While in the lysimeters no crops were grown in the soils, but they were allowed to leach; the drainage being collected and analyzed.

Soil was taken from fallow land, wheat land and alfalfa land. The soils were kept in lysimeters from Nov., 1904 to Oct., 1906. The nitrates expressed in grammes HNO_3 per square metre surface amounted to 40 Gm. from the fallow land and 48 Gm. from the wheat land in the lysimeters 25 cm. deep and 66 Gm. from the fallow land, 77 Gm. from the wheat land and 78 Gm. from alfalfa land in lysimeters 50 cm. deep. With Ebermeyer lysimeters, which are funnels placed under a column of soil in the field by hollowing out the soil under the column, they also obtained more nitrates in the drainage from wheat soil than from fallow land, both where the column of soil was 25 cm. deep and where it was 50 cm. deep.

King and Whitson [4] report an experiment in which one of the two contiguous plats of oats had a crop entirely removed on June 20, on which date determinations of nitrates were made in the soil of both plats to a depth of four feet. The crop on the harvested plat was weighed and dry matter determined. At the end of nineteen days nitrates were again determined in both plats and the remaining oats were harvested, weighed and dry matter determined. No determinations of nitrogen were made in the crop, but the gain in nitrogen for the nineteen days was calculated from the dry weight on the basis of average analyses

[2] Ann. Agron. (1891), xvii, 49–82.

[3] Report of the Chem. Lab. of the Ploty Experiment Station for 1905.

[4] Wisconsin Sta. Bulletin No. 93.

for oat plants at that stage. The gain in nitrogen in the oat plants growing for the 19 days minus the loss of nitrates during that time was twice as great as could be accounted for by the gain of nitrates on the bare plat. No account was taken of the nitrogen in the plant roots which would make a still greater difference. The authors suggest that the discrepancy may have been due to failure to obtain all of the nitrates from the soil in the process of analysis. While an error of this kind doubtless existed it must be remembered that the results hinge on nitrate determinations on both plats which should practically neutralize this error.

Similar results with clover were obtained by the same investigators, but being a legume this may be accounted for by processes already understood.

The same investigators [5] determined nitrates in soils to a depth of four feet under corn, potatoes, alfalfa and clover.

As between the cultivated crops corn and potatoes there was a fairly definite relation, the nitrates being higher under the corn. The soil under the non-cultivated crops was naturally lower in nitrates.

Stewart and Greaves [6] in a study of nitrates in irrigated soils planted to corn, potatoes and alfalfa and also on fallow land during a period of three years, and oats one year give figures that show nitrates to be higher under corn than under potatoes and considerably lower under alfalfa and oats. The fallow frequently contained less nitrates than corn land and sometimes less than potato land. They also found that there was a steady loss of nitrates in corn and potato soil after the growing period had ceased while fallow plats similarly cultivated did not show nearly as large a loss. Alfalfa land maintained an almost constant nitrate content throughout the year while corn and potato land showed a decline.

SIGNIFICANCE OF EXPERIMENTS CITED.

The bearing which these results have on the hypotheses presented in this paper is to be found in the occurrence of nitrates in soil under crops in excess of those in similar soil

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[5] Wisconsin Sta. Bulletin Nos. 85 and 93.

[6] Utah Agricultural Experiment Station Bulletin No. 106.

uncropped, and in the drainage water of previously cropped soil in greater quantity than in drainage water from similar soil previously in fallow. These phenomena raise the question as to what relation certain plants may have to nitrates either in their production or removal. The more or less definite relation in any one soil between the kind of crop and the quantity of nitrates under it leads to the question whether this relationship differs with different plants.

INVESTIGATIONS AT THIS STATION.

In 1907, 1908, and 1909 determinations of nitrates were made in field plats under timothy, corn and oats in rotation the results of which led us to investigate further the relation of the plant to the nitrate content of the soil. The earlier determinations were from samples of soil taken to a depth of only eight inches, but later samples were taken of each foot of soil to a depth of four feet.

EXPERIMENTS ON PLATS MANURED FOR TIMOTHY.

Experiment plats each one-tenth acre in size were used in this experiment. They were in rotation of timothy three years, corn, oats, and wheat each one year, and had been fertilized in different ways for timothy, but received no fertilizer for the grain crops which followed. There were twenty-two plats in all. Their treatment is shown in Table I.

On these plats samples of soil were taken to a depth of eight inches at intervals during the growing season and after the timothy and oats had been removed. The entire twenty-two plats were sampled on the same day or on two contiguous days. The samples were removed from the earth by means of a soil auger. Twelve borings were removed from each plat. These were thoroughly mixed on an oilcloth surface and a pint sample placed in a glass jar. The sample was brought to the laboratory and moisture and nitrates determined, the former by drying to constant weight at the temperature of boiling water, and the latter by the phenoldisulphonic acid method, comparisons with a standard nitrate solution being made by means of the colori-meter designed by Schreiner.

In 1908 and 1909 when the plats were planted to corn and oats respectively, an unplanted space was left for twenty-five

feet on the north end of each plat. This unplanted space was cultivated when the plats were in corn, receiving the same cultivation as did the planted portion of the plat. When the

TABLE I.

Crop Rotation and Fertilizer Treatment of Plats Manured for Timothy.

Plat No.	Fertilizer treatment per acre in 1905–1907, Crop, timothy	Corn, 1908	Oats, 1909
711	No fertilizer..........................		
712	320 lbs. rock superphosphate.........		
713	80 lbs. muriate of potash.............		
714	No fertilizer..........................		
715	160 lbs. nitrate of soda..............		
716	320 lbs. rock superphosphate.........		
	160 lbs. nitrate of soda..............		
717	No fertilizer..........................		
718	320 lbs. rock superphosphate.........		
	80 lbs. muriate of potash.............		
719	160 lbs. nitrate of soda..............		
	80 lbs. muriate of potash.............		
720	No fertilizer..........................		
721	160 lbs. nitrate of soda..............		
	80 lbs. muriate of potash.............		
	320 lbs. rock superphosphate.........		
722	160 lbs. nitrate of soda..............		
	80 lbs. muriate of potash.............	No ferti-	No ferti-
	640 lbs. rock superphosphate.........	lizer or ma-	lizer or ma-
723	No fertilizer..........................	nure ap-	nure ap-
724	320 lbs. nitrate of soda..............	plied	plied
	80 lbs. muriate of potash		
	640 lbs. rock superphosphate.........		
725	320 lbs. nitrate of soda..............		
	80 lbs. muriate of potash.............		
	320 lbs. rock superphosphate.........		
726	No fertilizer..........................		
727	320 lbs. nitrate of soda..............		
	80 lbs. muriate of potash.............		
	320 lbs. rock superphosphate.........		
728	640 lbs. nitrate of soda..............		
	80 lbs. muriate of potash.............		
	320 lbs. rock superphosphate.........		
729	No fertilizer..........................		
730	No fertilizer..........................		
731	1905, 10 tons manure applied; 1906, no manure; 1907, 10 tons manure		
732	1905, 20 tons manure applied; 1906, no manure; 1907, 20 tons manure		

plats were in oats the unplanted space was kept free from weeds by scraping with a hoe. Soil samples were taken from the planted and unplanted portions of each plat on the same dates,

which permits of a comparison of the effect of a certain soil treatment on the uncropped as well as on the cropped soil. It also serves to show the relation of the crop to the nitrates in the soil naturally a very important factor in their occurrence.

Table II contains a statement of the nitrate content of each plat on the dates sampled during the three years. At the foot of the table is the average for all plats on the dates analyzed, and below that is the average for all unfertilized and unmanured plats. The last, by eliminating the effect of nitrate fertilizers, is a somewhat better index to the normal course of nitrification than is the average of all the plats.

The timothy had been on the land for two years previous to 1907 and there was a good stand. The commercial fertilizers had been added twice and the farm manure once in the two years. For the crop of 1907, farm manure was applied as a top dressing on October 2, 1906, to the plats designated in Table I and the commercial fertilizers were applied April 23–24, 1907. The samples were taken April 23, immediately before the fertilizers were applied. The timothy was cut July 23 and samples for nitrates were taken the next day. The corn was planted May 29 and cut Sept. 24. No fertilizers or manure was applied to either the corn or oats. The oats were drilled in on April 23, the day following the first sampling for nitrates. They were harvested on Aug. 6, and samples taken the following day.

SEASONAL RANGE OF NITRATES UNDER TIMOTHY, CORN, AND OATS.

A striking feature of the nitrate content of the timothy plats is the uniformity and scarcity of nitrates throughout the growing season. In all but the nitrate fertilized plats the nitrate content was higher in April and August than during the period of more active growth. The land had not been plowed for two years and was covered with a thick sod, neither of which conditions were favorable for nitrification. The season range of nitrates under the timothy resembled that under alfalfa in the experiments of King and Whitson and Stewart and Greaves. During the first half of May, when growth first became active there was a tendency for the nitrates to increase as shown by the analyses of May 3 and 14, there was then a decrease during

TABLE II.

NITRATES (NO$_3$, P. P. M., DRY SOIL) IN PLATS 711-732 AT CERTAIN PERIODS DURING THREE YEARS.

Plat. No.	Timothy, 1907										Corn, 1908						Oats, 1909			
	Apr. 23	May 3	May 14	May 22	May 24	June 6	June 13	June 20	July 24	Aug. 14	S M May 19	S M June 22	N M July 6	S M July 27	N M Aug. 10	Sept. 17	Apr. 22	June 24	July 12	Aug. 7
711 ch.	4.2	4.6	1.3	1.9	3.2	3.5	4.6	3.9	5.3	7.2	25.1	40.3	62.0	182.0	162.5		93.8	37.8	7.6	9.8
712.	5.0	3.3	5.2	2.6	4.6	6.0	2.6	1.2	5.8	8.4	31.5	31.5	52.9	172.0	162.5		61.2	14.2	6.9	3.2
713.	11.3	2.7	1.3	1.6	3.3	2.6	2.6	2.7	5.5	6.0	14.5	52.0	89.6	268.0	237.6		44.2	24.7	8.6	10.8
714 ch.	16.0	4.6	8.0	1.9	4.6	2.6	2.6	2.1	5.5	7.8	22.4	40.3	58.8	172.0	201.5		60.2	18.1	6.7	10.5
715.	14.6	9.0	6.9	1.9	3.3	3.9	4.0	1.2	5.6	9.6	25.8	52.0	89.6	268.0	156.0		56.0	5.0	7.9	10.8
716.	13.0	6.2	8.0	1.6	2.0	1.8	2.6	1.8	5.0	3.6	32.6	69.1	51.2	194.0	234.0		31.7	16.0	5.0	7.8
717 ch.	11.4	9.0	4.0	1.3	3.3	2.7	2.4	2.7	5.0	6.0	25.8	47.3	47.3	211.0	156.0		56.0	5.0	9.0	10.8
718.	6.6	1.3	1.6	1.3	2.4	1.8	1.8	1.3	2.9	4.2	11.4	47.1	44.7	211.0	160.0		26.4	12.8	3.8	1.2
719.	6.0	3.3	1.9	1.9	3.3	1.7	1.6	0.9	3.5	6.0	16.7	31.5	46.6	178.0	136.5	49.5	50.1	2.6	3.8	1.6
720 ch.	8.0	2.0	4.0	0.6	8.4	1.8	3.3	1.8	5.0	7.8	20.1	30.2	51.2	224.0	160.0	32.0	66.0	2.6	6.0	0.8
721.	4.8	4.1	4.7	0.6	2.8	1.4	1.0	1.2	2.4	1.8	20.7	38.4	44.7	211.0	201.6		30.3	14.7	4.5	1.4
722.	3.3	9.5	2.0		3.9	1.2	1.8	1.3	3.0	4.8	12.0	32.2	50.4	208.0	198.0		40.2	21.1	4.6	1.0
723 ch.	5.7	6.1	2.7		2.6	2.2	1.0	1.3	3.4	5.4	11.4	47.1	56.3	194.0	117.0	49.5	29.7	4.0	4.9	1.1
724.	5.0	2.0	1.4		2.1	2.4	1.3	2.9	3.0	6.0	21.4	49.2	44.7	194.0	105.6		26.8	3.9	3.1	2.2
725.	10.3	34.1	14.1	4.0	2.8	2.2	1.8	1.8	3.0	6.6	10.7	36.5	56.3	228.0	147.4		41.5	2.9	4.9	1.4
726 ch.		13.7	37.5	0.6							15.2	50.4	75.4	194.0	170.6		59.4	4.6	4.5	2.2
727.			8.0								14.7	42.2	80.6	178.0	165.0		45.5	3.3	3.1	1.6
728.			4.7								21.4	49.2	100.8	158.0	178.2		44.2	3.9	3.5	1.2
729 ch.	12.3	51.6	72.1	22.1	2.8	7.8	50.0	8.4	6.5	7.8	4.0	24.8	50.4	158.0	151.8	49.5	45.5	16.0	3.5	2.2
730 ch.	8.2				3.9		0.8	1.3	2.2	2.4	6.7	27.3	50.4	150.0	151.8		49.5	5.0	3.4	1.4
731.	8.5	4.1	8.0	1.9	2.6	2.4	1.1	1.3	2.3	1.8	4.3	26.4	70.5	198.0	178.2		44.2	16.0	6.0	1.0
732.	21.0	4.6	97.4	47.4	39.1	7.8	50.0	8.4	2.8	2.4	44.2	64.0	105.6	251.0	184.8	75.0	63.3	10.4	6.2	2.6
Average.	9.2	9.3	15.6	5.6	5.3	2.4	4.4	2.2	4.2	5.2	17.5	41.3	62.8	191.7	165.3	52.1	48.1	11.1	4.6	3.7
Av. for unfertilized plats	8.9	3.5	3.9	1.5	3.4	2.4	2.5	2.3	4.0	5.4	14.6	38.1	67.5	193.6	180.7	49.5	50.7	16.1	4.1	3.4

the remainder of May and during June, with a slight increase at the time of harvest, which was continued in the middle of August when the aftermath was growing.

The timothy sod was plowed under in the autumn of 1907, but nitrification had not proceeded very rapidly up to the time of the first analysis on May 19. The most noticeable increase was between July 6 and July 28. At the latter date there was a very large accumulation of nitrates in the soil, probably the maximum of the season. This period of active nitrification was also the time during which the corn was making its most active growth. The weather was warm and very favorable for the growth of corn, which was an unusually good crop this year. It is a striking fact that in spite of the pronounced growth of the corn at this time the nitrates increased at a rate which gave no appearance of their being used by the crop.   ·

Between July 28 and Aug. 10 there was a perceptible decline in the nitrate content, and between Aug. 10 and Sept. 17 this decline was very marked. It is strange that the diminution in nitrates should take place after the period of growth during which the corn plant has been shown to absorb fully one-half of the nitrogen it utilizes.

The analyses of April 22, 1909 which were made before the oats were planted show a much higher nitrate content in the soil in the spring following corn than following timothy, although the analyses were made nearly a month earlier in 1909 than in 1908. Between April 22 and June 24 there was quite a loss of nitrates, as is to be expected from the fact that the nitrogen absorption of the crop is greatest at that time. The lowest figures for nitrates were, however, on July 12 and Aug. 7, although the crop could not have been making very heavy drafts at that time, especially at the latter date, and in the face of the fact that nitrification was at its maximum at those dates under the corn crop.

Indeed it seems that nitrification is not, in the main, determined by the season of the year, but is closely related to the development of the crop. It might be concluded from these data that nitrification is most pronounced during the active growth of the crop upon the soil, and decreases with the less vigorous growth of the crop.

NITRATES ON THE PLANTED AND BARE PORTIONS OF THE PLATS.

As before stated a portion of each plat was not planted in 1908 and 1909, but was given, as closely as possible, the same treatment as the planted portion of the plat. When the planted part of the plat was in corn the bare space was given the same cultivation, and when oats were growing on the planted portion of the plat the bare section was kept free from weeds by scraping the surface with a hoe. In 1908 bare spaces were maintained on the north and south ends of each plat for a distance of 25 feet from each end. When the north end bare space was sampled the north half of the planted area was sampled on the same date, and the same was done with the south part of the plat. The north and south halves were sampled alternately. In 1909 all samples were taken from the south halves of the plats, the bare and planted portions corresponding exactly with those of the previous year. These are referred to as the " north ends," " south ends," " north middles " and " south middles."

A comparison of the nitrate content of the bare and planted parts of the same plat serves to indicate what the effect of the crop has been on the nitrate content of the soil. Table III contains these figures for the years 1908 and 1909.

A striking feature of the nitrate content of the soil during certain stages in the growth of corn is the close agreement between the nitrates in the planted and bare portions of the plats. This is particularly noticeable in the analysis of July 27 previous to which the corn crop must have absorbed about one-half of its nitrogen, judging by what is known of the life-history of the plant. The previous heavy draft on soil nitrates is indicated by the analyses of June 22 and July 6, both of which show a lower nitrate content in the planted sections of the plats. The analyses of July 27 indicate either that the production of nitrates is proceeding much more rapidly in the cropped than in the uncropped soil, or else that the corn crop is absorbing part of its nitrogen in some form other than as nitrates.

The analyses of Aug. 10 show a decline of the nitrates on the planted areas, while the nitrates still continue to increase on the bare spaces. From the stand-point of nitrogen utilization by the crop the decline in nitrates at this late date is difficult to account for.

TABLE III.

NITRATES (NO₃, P. P. M., DRY SOIL) IN PLANTED AND UNPLANTED SECTIONS OF PLATS 711–732, FOR TWO YEARS.

Plat. No.	Corn, 1908										Oats, 1909							
	May 19		June 22		July 6		July 27		Aug. 10		Apr. 22		June 24		July 12		Aug. 7	
	Bare	Planted	Bare	Planted	Bare	Planted	Bare	Planted	Bare	Planted	Bare	Planted	Bare	Planted	Bare	Planted	Bare	Planted
711 ch.	17.0	25.1	33.0	40.3	64.4	62.0	158.0	182.0	179.2	162.5	63.6	93.8	59.0	37.8	36.2	7.6	63.1	9.8
712	9.5	10.3	50.4	31.5	74.4	52.9	194.0	172.0	176.4	162.5	85.0	61.2	51.6	14.2	56.0	6.9	70.0	3.2
713	35.3	14.5	38.4	40.3	63.4	58.8	198.0	172.0	119.7	201.5	74.8	44.2	77.5	24.7	39.4	8.6	60.8	10.5
714 ch.	15.2	22.4	53.7	52.0	63.0	89.6	221.0	268.0	188.5	237.0	86.2	60.2	34.8	18.1	127.0	6.7	56.0	8.0
715	29.0	25.8	44.2	57.2	49.8	60.5	221.0	211.0	163.8	158.4	86.2	56.0	93.1	10.0	129.0	7.9	82.8	10.8
716	30.3	32.6	45.5	69.1	41.6	47.3	255.0	261.0	204.6	156.0	113.8	31.7	48.6	5.0	70.0	5.6	75.0	7.8
717 ch.	21.1	20.1	64.0	43.5	46.5	39.0	202.0	211.0	231.0	234.0	112.2	45.5	74.3	16.0	24.0	2.8	86.0	2.4
718	14.0	11.7	47.8	36.5	44.0	39.7	147.0	224.0	156.0	140.8	81.9	56.7	41.1	2.6	48.0	2.5	79.0	2.0
719	18.8	21.4	39.7	30.2	52.7	30.5	176.0	178.0	195.0	160.0	99.4	66.0	58.3	19.2	37.8	2.5	93.7	2.8
720 ch.	19.5	16.7	42.8	31.5	70.5	102.4	156.0	211.0	184.8	136.5	81.2	50.1	51.6	12.8	34.0	3.8	77.1	3.3
721	26.8	20.1	53.7	38.4	97.6	66.5	194.0	130.0	198.0	151.8	77.0	36.4	14.3	2.6	12.2	2.5	119.0	4.2
722	24.7	12.0	31.5	32.2	70.5	46.0	194.0	97.5	158.4	138.0	62.7	26.4	70.4	3.9	36.0	4.5	127.0	2.6
723 ch.	19.7	11.4	38.4	47.1	48.0	44.7	147.0	141.0	201.6	198.0	89.1	40.2	65.0	3.9	64.7	4.5	85.4	0.8
724	19.7	11.6	47.3	36.5	54.8	50.4	201.0	208.0	184.8	117.0	81.6	30.3	97.0	3.9	41.5	4.9	85.8	1.6
725	19.0	21.4	46.7	50.4	54.5	56.3	194.0	194.0	136.5	105.0	80.4	29.7	60.9	3.3	32.3	2.5	100.0	1.2
726 ch.	17.0	10.7	40.3	38.4	39.0	51.2	194.0	228.0	136.0	147.0	50.2	26.8	48.5	4.6	61.2	3.1	65.7	1.1
727	17.0	15.2	40.3	49.2	34.3	75.4	174.0	194.0	178.2	171.6	71.4	41.5	24.9	2.9	59.7	6.4	64.8	1.4
728	22.1	14.7	56.3	42.2	104.1	80.0	168.0	178.0	153.6	165.0	85.0	59.4	32.5	3.9	68.5	0.0	135.0	2.2
729 ch.	17.4	4.0	35.3	24.8	83.7	100.8	172.0	158.0	188.5	178.2	83.8	45.5	66.5	21.1	59.0	3.5	31.9	1.1
730 ch.	7.2	6.7	42.8	27.3	103.7	50.4	195.0	150.0	221.0	151.8	55.9	44.2	50.4	14.7	46.0	3.4	51.5	1.0
731	36.1	14.3	81.9	26.4	46.9	70.5	238.0	198.0	227.5	178.2	105.6	49.5	47.7	9.0	65.5	3.8	67.0	1.4
732	45.5	44.2	79.3	64.0	103.7	105.6	304.0	251.0	147.2	184.8	122.1	63.3	57.6	10.4	78.9	6.2	114.0	2.6
Average.	21.9	17.5	48.1	41.3	64.1	62.8	186.8	191.2	178.6	165.3	84.0	48.1	55.7	11.1	55.8	4.6	81.6	3.7
Aver. of unfertilized plats.	16.7	14.6	44.6	38.1	64.9	67.5	180.6	193.6	191.3	180.7	77.7	50.7	56.2	16.1	56.6	4.1	64.6	3.4

The analyses of April 22, 1909, made before the oats were planted shows a continuation of the more rapid decline on the corn land than on the uncropped spaces. The next analysis, June 24, shows an expected decline in the nitrate content of the cropped portions of the plats, as does also that of July 12. By the latter date the nitrogen utilized by the oat crop has, in large part, been absorbed. The last analysis, Aug. 7, shows, however, a still greater decrease in the nitrate content, when we might expect a partial recovery, and when the nitrate content of the uncropped soil has made a very great increase.

Comparing the two crops the following facts are quite significant.

1. When nitrification is at its maximum in the corn land the cropped soil contains more nitrates than the uncropped.

2. In oat land the nitrates are never so high in the cropped as in the uncropped soil.

3. While the maximum nitrate content in the uncropped soil occurred at about the same dates in both years, that in the cropped soil varied with the crops.

4. Under both crops the nitrate content was higher during the period when the crop was making its greatest draft on the soil nitrogen than in the later stages of growth, and this in spite of the fact that the nitrates in the uncropped soil were increasing while those in the cropped soil were disappearing.

These phenomena are explainable on the assumption that nitrification is stimulated by some processes connected with the active growth and absorbing functions of the plant roots, and is inhibited by the conditions accompanying the decreasing activities of the roots.

The large differences in the nitrates under these crops as well as under the corn, potatoes, alfalfa and oats grown by King and Whitson and by Stewart and Greaves may, aside from the influence of cultivation, be sought in the inherent differences between plants of different species in their stimulating or inhibiting effect on nitrification. Another factor which also may be operative in determining the quantity of nitrates is the habits of the plant in respect to the form in which it absorbs nitrogen. It is possible that a plant may induce an active nitrification in the soil and yet absorb its nitrogen largely in the form of

ammonia or even to a certain extent in the form of organic nitrogen, as experiments we are now conducting with corn indicate.

The response of different plants to nitrogen in different forms indicates a difference in their abilities to utilize this material when in certain compounds. Grass, for instance, makes a quick and effective response to sodium nitrate and the nitrate content of the soil, unless heavily dressed with nitrate fertilizer, is maintained at a very low point. Oats are less responsive to the nitrate fertilizer and do not reduce the nitrate content of the soil so low. Corn is but little affected by a nitrate fertilizer, while it is greatly benefitted by fresh applications of farm manure. The nitrates meanwhile are present, apparently greatly in excess of the needs of the plant.

THE RELATION OF NITRATES TO SOIL MOISTURE.

Moisture determinations were made in all soil samples in which nitrates were determined, besides which daily determinations of moisture were made in certain of the unfertilized plats during the summers of 1907 and 1908. It was thought that a record of the moisture content for a period preceding the nitrate determinations would show the relation between soil moisture and nitrate formation better than would a statement of the moisture content on the day on which nitrates were determined. The nitrate content and the average moisture content of the soil for the time intervening between the dates on which nitrates were determined are given in Table IV.

Plat 711 ran perceptibly lower in moisture and higher in nitrates in 1907 than did plat 720. In 1908 there was little difference in moisture and no consistent difference in nitrates. In the latter part of July and first part of August there was a decrease in moisture content in both plats for both years, but in 1907 this was accompanied by an increase in nitrates while in 1908 a decrease occurred. The drying out of the soil and consequent aeration apparently does not appear to produce the same result in both cases, from which it may be taken for granted that factors other than this are more important in nitrate formation.

TABLE IV.

AVERAGES OF DAILY DETERMINATIONS OF SOIL MOISTURE FOR THE PERIODS INTERVENING BETWEEN NITRATE DETERMINATIONS ON CROPPED SOIL.

TIMOTHY, 1907

Plat No.	June 4–6		June 7–13		June 14–20		June 21–July 24		July 25–Aug. 14	
	Moisture, per cent.	Nitrates, p.p.m.	Moisture, per cent.	Nitrates, p.p.m.	Moisture, per cent.	Nitrates, p.p.m.	Moisture, per cent.	Nitrates, p.p.m.	Moisture, per cent.	Nitrates, p.p.m.
711	22.8	3.5	23.4	4.6	23.8	3.9	21.7	5.3	17.9	7.2
720	26.3	1.8	26.3	1.8	27.0	1.2	25.1	2.9	21.2	6.0

CORN, 1908

Plat No.	June 2–22		June 23–July 6		July 7–28		July 29–Aug. 10	
	Moisture, per cent.	Nitrates, p.p.m.	Moisture, per cent.	Nitrates, p.p.m.	Moisture, per cent.	Nitrates, p.p.m.	Moisture, per cent.	Nitrates, p.p.m.
711	22.7	40.3	21.1	62.0	24.0	182.0	22.1	162.5
720	22.6	31.5	21.5		25.3	211.0	22.8	136.5

CHANGES IN SOIL MOISTURE.

While the gradual changes in soil moisture content that have been examined do not appear to have been an important factor in promoting nitrification, at least not sufficient to prevail over other influencing conditions, the question arises whether the more

TABLE V.

DAILY MOISTURE CONTENT OF CERTAIN TIMOTHY PLATS IN 1907.

Moisture in soil, per cent. in water-free soil				Moisture in soil, per cent. in water-free soil				
Date 1907	Plat 711	Plat 720	Plat 728	Plat 729	Date 1907	Plat 711	Plat 720	Plat 728	Plat 729
June 6	23.3	27.3	25.0	27.5	July 14	....	....	....	....
June 7	30.7	32.6	29.9	34.5	July 15	23.3	26.1	23.7	26.6
June 8	25.0	27.5	24.5	28.0	July 16	20.9	23.4	23.3	24.0
June 9	....	....	....	....	July 17	20.0	24.2	23.7	25.1
June 10	....	....	....	....	July 18	21.9	25.1	23.7	26.4
June 11	21.2	23.4	20.7	23.4	July 19	18.9	22.1	19.7	22.1
June 12	20.9	23.7	....	23.4	July 20	18.7	22.6	20.3	22.1
June 13	19.3	24.5	20.6	23.3	July 22	19.0	20.9	20.4	24.2
June 14	19.0	23.0	18.9	21.7	July 23	15.6	20.9	19.0	22.5
June 15	18.9	23.4	17.6	22.8	July 24	16.0	20.1	18.7	21.2.
June 16	....	....	....	....	July 25	....	....	....	....
June 17	23.0	24.6	20.6	25.4	July 26	16.8	20.0	19.6	21.7
June 18	14.9	18.6	16.6	18.9	July 27	16.6	19.3	16.0	20.7
June 19	30.3	32.6	31.0	32.4	July 28	....	....	....	....
June 20	37.2	40.0	37.1	41.8	July 29	15.6	19.7	17.5	21.3
June 21	35.1	38.8	36.8	40.2	July 30	14.9	18.7	16.8	20.0
June 22	21.0	24.0	22.2	25.6	July 31	14.5	21.2	17.6	19.6
June 23	....	....	....	....	Aug. 1	16.1	19.4	17.5	21.2
June 24	18.7	22.1	19.3	22.8	Aug. 2	20.1	25.3	23.4	25.6
June 25	18.6	22.4	17.3	23.6	Aug. 3	21.0	23.3	23.8	24.6
June 26	22.4	24.6	21.9	27.3	Aug. 4	....	....	....	....
June 27	22.8	20.3	18.6	23.8	Aug. 5	21.3	22.6	23.0	23.6
June 28	20.6	Lost	19.6	25.3	Aug. 6	19.7	24.2	24.0	25.4
June 29	19.4	21.7	17.7	22.2	Aug. 7	19.4	23.0	22.5	23.1
June 30	....	....	....	....	Aug. 8	18.6	21.9	22.6	23.6
July 1	26.4	29.7	28.2	31.0	Aug. 9	18.7	22.5	22.2	23.1
July 2	27.5	31.0	29.3	29.5	Aug. 10	18.9	21.0	20.9	22.5
July 3	25.6	28.2	27.5	27.5	Aug. 11	....	....	....	....
July 4	....	....	....	....	Aug. 12	17.5	19.9	20.4	19.1
July 5	24.2	27.0	25.3	27.0	Aug. 13	18.3	19.3	21.0	21.2
July 6	22.5	25.4	24.0	25.7	Aug. 14	16.6	20.1	18.7	20.1
July 7	....	....	....	....	Aug. 15	15.7	17.9	17.6	19.9
July 8	20.0	23.7	23.3	23.8	Aug. 16	16.2	17.3	17.7	18.9
July 9	19.6	23.6	21.6	23.7	Aug. 17	15.2	17.2	16.4	17.5
July 10	18.7	20.7	19.3	21.5	Aug. 18	....	....	....	....
July 11	19.4	20.6	20.9	19.7	Aug. 19	14.8	16.4	13.3	15.0
July 12	25.9	31.2	29.9	30.2	Aug. 20	12.4	16.5	15.2	15.3
July 13	26.4	29.2	28.2	29.2					

frequent, although less marked changes in moisture content, due to the effect of transpiration from the plant in drying out the soil between rains would not cause greater nitrification on the planted than on the unplanted sections of the plats.

Analyses made in the course of the experiments here described give the daily moisture content of the planted sections

on certain plats throughout the growing season. There were also moisture determinations made in each of the soil samples, in which nitrates were determined, and these show to what extent the cropped soils dried out as compared with the uncropped soils. These data are given in Tables IV to VII respectively.

It will be seen from these tables that while there is considerable range in the maximum and minimum moisture content of these plats that the changes are not rapid, at least the

TABLE VI.

Daily Moisture Content of Certain Corn Plats in 1908.

Date 1908	Plat 711 S M	Plat 720 S M	Plat 728 S M	Plat 729 S M	Date	Plat 711 S M	Plat 720 S M	Plat 728 S M	Plat 729 S M
June 2	27.3	26.8	26.5	26.5	July 11	24.0	21.7	21.7	21.3
June 3	25.1	25.7	26.1	24.2	July 13	26.8	26.7	27.5	26.1
June 4	26.1	24.0	25.0	24.2	July 15	23.1	25.1	24.2	25.0
June 5	24.6	24.8	24.5	23.8	July 16	21.0	23.6	23.7	23.3
June 6	23.8	24.5	23.6	23.3	July 18	22.5	24.2	24.2	22.8
June 8	21.9	21.2	22.2	20.3	July 20	21.7	22.8	23.8	22.2
June 9	20.3	21.6	22.8	21.3	July 21	21.7	22.6	23.7	22.6
June 10	20.9	21.7	22.6	21.5	July 22	26.4	29.7	28.7	28.0
June 11	22.1	21.5	21.7	20.6	July 23	26.4	28.8	27.8	27.2
June 12	20.3	20.9	21.2	21.2	July 24	24.2	26.8	26.5	25.6
June 13	23.6	21.5	23.8	20.7	July 25	28.8	30.3	31.9	27.8
June 16	22.5	23.4	23.4	22.8	July 27	26.8	28.5	26.7	26.7
June 17	21.6	22.4	22.8	22.4	July 28	24.8	27.0	27.2	27.5
June 19	20.	20.7	22.8	22.1	July 29	23.6	25.1	25.1	23.0
June 20	22.1	21.0	21.3	20.7	July 30	23.4	24.2	24.2	22.8
June 22	21.5	21.2	22.4	20.9	July 31	22.4	22.5	24.3	22.1
June 23	21.0	22.6	22.2	21.5	Aug. 3	19.3	19.9	21.0	19.6
June 24	21.5	21.7	22.2	21.3	Aug. 4	18.7	20.3	21.3	19.1
June 25	20.6	21.5	23.3	21.5	Aug. 5	23.0	21.9	23.4	23.0
June 26	20.6	21.3	22.6	21.5	Aug. 6	22.1	23.1	24.6	23.1
June 27	21.7	21.2	23.1	21.7	Aug. 8	24.5	25.6	25.7	25.9
June 29	20.1	20.9	23.3	20.6	Aug. 11	21.0	20.7	23.1	23.0
June 30	21.6	21.7	22.5	21.3	Aug. 12	20.9	21.0	23.0	21.3
July 1	21.5	21.2	22.6	20.7	Aug. 13	18.2	19.0	21.6	20.9
July 2	20.7	21.5	....	19.6	Aug. 14	21.3	22.2	23.1	22.2
July 3	21.3	21.2	22.4	20.0	Aug. 18	22.5	22.4	24.5	24.2
July 7	20.9	21.0	21.5	20.9	Aug. 19	21.2	22.4	24.6	21.7
July 8	23.1	23.4	24.6	23.1	Aug. 20	21.6	21.7	23.0	21.7
July 9	22.5	22.6	23.8	22.1	Aug. 21	20.0	21.0	21.9	21.7

drying-out process is slow and that is the one that causes aeration. Furthermore, it is quite apparent that on the corn soil in which nitrification is most active, the changes in the moisture content of the cropped soil do not differ greatly from those on the uncropped soil on the same dates. It is also very evident that the changes in the moisture content go on all through the summer and should therefore induce nitrification during the later growth of the crop as well as in the early stages, while Table II shows that nitrification is greater on the planted soil only during the

earlier stages of growth. While soil moisture content is undoubtedly a factor in nitrification in this soil under otherwise similar conditions and in some soils may be the controlling influence, the effect in these plats was evidently counterbalanced

TABLE VII.

MOISTURE CONTENT FOR PLANTED AND BARE SECTIONS OF CORN PLATS IN 1908 ON DATES DESIGNATED.

Date	Plat 711, unplanted S	Plat 711, planted S M	Plat 720, unplanted S	Plat 720, planted S M	Plat 728, unplanted S	Plat 728, planted S M	Plat 729, unplanted S	Plat 729, planted S M
June 3	27.0	25.1	....	....	....	....	....	....
June 4	....	....	23.3	24.0	....	....	....	....
June 5	....	....	....	....	25.0	24.5	....	....
June 6	....	....	....	....	....	....	22.6	23.3
June 9	21.6	20.3	....	....	....	....	....	....
June 10	....	....	21.0	21.7	....	....	....	....
June 11	....	....	....	....	23.1	21.7	....	....
June 12	....	....	....	....	....	....	21.5	21.2
June 16	23.6	22.5	....	....	....	....	....	....
June 17	....	....	21.9	22.4	....	....	....	....
June 19	....	....	....	....	24.5	22.8	....	....
June 20	....	....	....	....	....	....	21.0	20.7
June 24	22.5	21.5	....	....	....	....	....	....
June 25	....	....	21.5	21.5	....	....	....	....
June 26	....	....	....	....	23.1	22.6	....	....
June 27	....	....	....	....	....	....	22.1	21.7
June 30	21.7	21.6	....	....	....	....	....	....
July 1	....	....	20.6	21.2	....	....	....	....
July 2	....	....	....	....	23.3	....	....	....
July 3	....	....	....	....	....	....	21.3	20.0
July 8	24.6	20.1	....	....	....	....	....	....
July 9	....	....	23.4	22.6	....	....	....	....
July 11	....	....	....	....	23.4	21.7	....	....
July 13	....	....	....	....	....	....	28.2	26.1
July 16	24.5	21.0	....	....	....	....	....	....
July 18	....	....	23.4	24.2	....	....	....	....
July 20	....	....	....	....	25.0	23.8	....	....
July 21	....	....	....	....	....	....	23.0	22.6
July 23	28.0	26.4	....	....	....	....	....	....
July 24	....	....	26.4	26.8	....	....	....	....
July 25	....	....	....	....	31.7	31.9	....	....
July 27	....	....	....	....	....	....	27.2	26.7
July 29	24.5	23.6	....	....	....	....	....	....
July 30	....	....	22.6	24.2	....	....	....	....
July 31	....	....	....	....	24.6	24.3	....	....
Aug. 3	....	....	....	....	....	....	20.0	19.6
Aug. 5	21.0	23.0	....	....	....	....	....	....
Aug. 6	....	....	21.9	23.1	....	....	....	....
Aug. 8	....	....	26.7	25.6	....	....	....	....
Aug. 11	....	....	....	....	23.8	23.1	....	....
Aug. 12	....	....	....	....	....	....	21.7	21.3
Aug. 14	23.4	21.3	....	....	....	....	....	....
Aug. 18	....	....	23.3	22.4	....	....	....	....
Aug. 19	....	....	....	....	24.0	24.6	....	....
Aug. 20	....	....	....	....	....	....	22.1	21.7

by other factors. The more active nitrification in the cropped than in the uncropped soil during early growth and the reversal of this in a later period has no apparent relation to the moisture content of the soil.

(*To be continued.*)

THE AIR-BRAKE AS RELATED TO PROGRESS IN LOCOMOTION.

BY

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To consider for a moment the quantitative results of the improvements which have been mentioned as evidenced by the comparative stopping distances of trains equipped with the types of brakes referred to. The diagram (Fig. 18), shows concretely

FIG. 18.
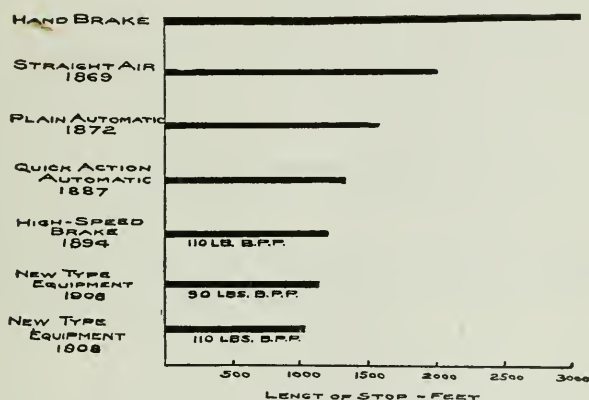
Diagram of development of air-brake efficiency since 1869.

the relative efficiency of the various forms of brakes for passenger trains, the difference in the length of the lines corresponding approximately to the reduction of distance required in which to stop a given train of one locomotive and six cars from a speed of 60 miles per hour since the introduction of the air-brake. If the diagram were inverted so that it is viewed upside down, a fair idea will be obtained of what the relation between the stops would have been through the respective periods of train development had there been no change in the air-brake since first applied.

The tendency of modern rolling stock to lower brake efficiency is further illustrated in Fig. 19. The retardation curves show

FIG. 19.
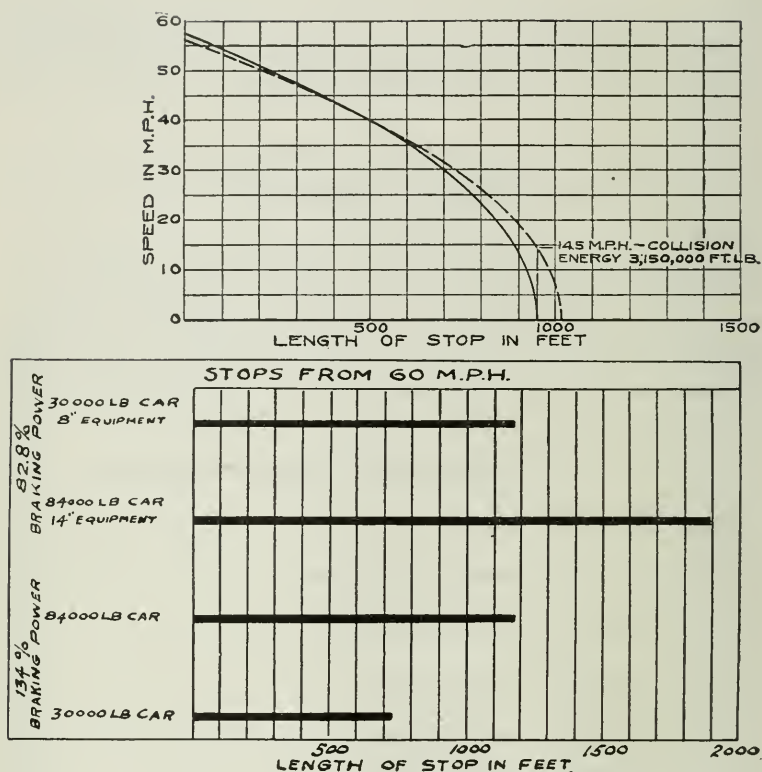
Comparative retardation curves and braking power chart for trains of 1875 and 1907.

Date	Speed in M.P.H.	Length of stop in feet	Time of stop in sec.	Weight of trains, tons	Work in ft.-tons performed by brakes			B. P., per cent.
					Total	Per sec.	Per brake-shoe per sec.	
1875	56.0	1020	22.0	227	23900	1086.4	14.70	82.8
1907	57.3	954	18.7	559	61300	3278 0	28.75	150.0

Dotted curve shows stop on Midland Railway, 1875, with the Westinghouse Automatic-Brake.

Full-line curve shows stop made on W. J. and S. R. R., 1907, with the Westinghouse "LN" Brake.

Had the braking power as shown in the last column of the table and represented by the full-line curve, been 134 per cent. instead of 150 per cent., the two stops would have been the same.

the stopping distance from about the same initial speed of a train composed of cars weighing 30,000 pounds and braking at 83 per cent. and a train of 84,000 pounds cars braking at 150 per cent. It will be seen that notwithstanding the 60 per cent. greater braking power of the heavier train, the difference in stop is not greatly in its favor. The reason for this is clear when it is considered that the work done during the stop for the light train was 14.5 foot-tons per brake-shoe per second while with the heavy train it was 29 foot-tons per brake-shoe per second, which shows that under modern conditions each brake-shoe is doing about twice the amount of work required formerly in order to make approximately the same stop, which consequently lowered the coefficient of friction and thus tended to equalize the actual retarding forces developed in the two cases.

The diagram below the comparative curves shows, first, the length of stop for light train with the equipment of its day; second, what the stop would have been with the heavier train had there been no change in brake equipment to correspond to the increased weight of train; third, what braking power was actually required to stop the heavy train in the distance the light train was stopped with its brake equipment; and fourth, what the stop of the light train would be if it were possible to apply to it the brake equipment required for the heavy train. This is a significant and all-sufficient example of what is required to meet modern conditions as effectively as they were provided for in the past.

CONTROL VALVE EQUIPMENT.

With the introduction of heavy sleeping cars and passenger equipment cars carrying heavy motive power apparatus such as self-contained motor cars, not only were the factors above mentioned, which tend to lower brake efficiency, aggravated to a marked degree, but limiting conditions were encountered in other directions. The brake force required to control such heavy (135,000 to 170,000 pound) cars with approximately the same effectiveness obtainable with the apparatus used on lighter cars became so great as to exceed the capacity of a single brake-cylinder even with the highest brake-cylinder pressure and greatest multiplication of its power by leverage that could be permitted.

The single brake-cylinder had already reached a maximum of 18 inches in diameter and it was generally agreed that a larger

size brake-cylinder would be impracticable from a manufacturing, operative and maintenance stand-point.

With 100 to 105 pounds brake-cylinder pressure being obtained from 110 pounds brake-pipe pressure carried there was little hope of raising the cylinder pressure higher and no material or permanent improvement in the general condition would result even if the full 110 pounds could be realized in the brake-cylinders.

There was no suggestion of an increase in brake-pipe pressure above the present standard, it being universally recognized that 110 pounds was about as high as could safely and economically be used with the type of apparatus and fixtures in general service.

The multiplication of the brake-cylinder pressure through the leverage of the foundation brake rigging had been carried, in many cases, beyond the recommended 9 to 1 maximum simply because it was the most obvious, simplest, and most convenient means of providing the heaviest cars with a proportionate braking power approaching that used on lighter cars. The evils of this expedient soon became manifest in dragging brake-shoes, " slow release " and trouble in keeping the brake rigging properly adjusted. Most important of all, from a safety stand-point, was the effect of this high leverage ratio in multiplying the losses due to lost motion in the rigging or truck members, brake-shoe movement and so on, the result of which was evidenced in excessive false piston travel and consequent failure to obtain the maximum brake-cylinder pressure contemplated in the design, or still more serious loss in braking power due to the piston travelling so far as to bottom on the cylinder head.

These and other mechanical limitations therefore barred further progress in this direction and two alternatives remained, viz. :

1. To increase the effectiveness of the single brake-cylinder as far as possible by using two brake-shoes per wheel (clasp brake).

2. To use two brake-cylinders per car.

While the first of these alternatives would undoubtedly be of some·assistance, there are objections to this design, not the least of which is a reasonable doubt whether the acknowledged theoretical advantages of the clasp brake would prove to be prac-

ticable; and a reasonable certainty that no matter to what extent its theoretical advantages might be realized in practice, the maximum increase in efficiency thus afforded could not be sufficient to meet the demands of conditions already existing, to say nothing of the possibilities of the future.

On the other hand, the two-brake-cylinder proposition did not necessarily involve any new or untried principles, since two complete equipments of the type already in service might be used, one for each end of the car. This would provide ample stopping power for existing conditions and lend itself readily to extension, as still more severe demands might arise. It was therefore recognized that such an arrangement offered the best solution of the problem of the proper air-brake equipment for passenger cars weighing 130,000 pounds or over. Furthermore, it was seen that a single valve mechanism to control the admission of air to and release of air from the two-brake-cylinders would possess such marked advantages over a complete double equipment for each car as to make a satisfactory and practicable design of such a valve greatly to be desired. In reality, the success and scope of the two-cylinder arrangement depended wholly on the characteristics of the valve device adopted for this purpose.

It was but logical that, in the first practical solution of this problem, use was made of the same principles, both of construction and operation, as had been embodied in a valve device already in use for some years and giving the best of satisfaction under conditions quite similar to those of the two-cylinder passenger-car equipment. While this valve (the distributing valve of the "ET" locomotive brake equipment) was particularly designed to operate in connection with two or more brake-cylinders on locomotives, its distinctive operative features were equally advantageous for passenger car service. Consequently, when the introduction of 85-ton multiple unit electric motor cars on the N. Y., N. H. & H. R. R. electric zone called for a correspondingly effective form of brake apparatus, of necessity using two-brake-cylinders, the valve mechanism adopted was a modification of the distributing valve type, the changes being only such as were required to adapt this device to passenger train service. From the start, its performance under the severe demands of suburban electric service was so satisfactory as to thoroughly establish the advantages of this type of equipment for the high braking

efforts and large brake-cylinders required by the heavier classes of
cars. It is hardly necessary, however, to go further into detail
regarding its construction or operation, first, because the design
of its operating mechanism resembles so closely that of the dis-
tributing valve, and, second, since it served to mark one stage
only in the development of a distinct type of brake apparatus for
such service.

As already stated, with the advent of passenger carrying cars
weighing from 135,000 to 150,000 pounds in steam road service
and still heavier motor cars, carrying extraordinary dead weight
loads, the limit of an efficient single-cylinder equipment was
approached and in some cases exceeded. But this was only one
phase of the situation. The demand of high speed heavy train
service had steadily advanced to a point where, for adequate con-
trol, something more was required of a brake than merely maxi-
mum retarding power in emergency. The ordinary service func-
tions and automatic safety and protective features became hardly
secondary in importance. Briefly stated, the requirements recog-
nized as essential in a satisfactory brake for this modern service
are as follows:

1. Automatic in action.
2. Efficiency not materially affected by unequal piston travel
or brake-cylinder leakage.
3. Prompt serial service action.
4. Graduated release.
5. Quick recharge and consequent ready response of brakes
to any brake-pipe reduction made at any time.
6. Predetermined and fixed flexibility for service operation.
7. Full emergency pressure obtainable at any time after a
service application.
8. Full emergency pressure applied automatically after any
predetermined brake-pipe reduction has been made after equaliza-
tion.
9. Emergency braking power approximately 100 per cent.
greater than the maximum obtainable in service applications.
10. Maximum brake-cylinder pressure .obtained in the least
possible time.
11. Maximum brake-cylinder pressure maintained throughout
the stop.
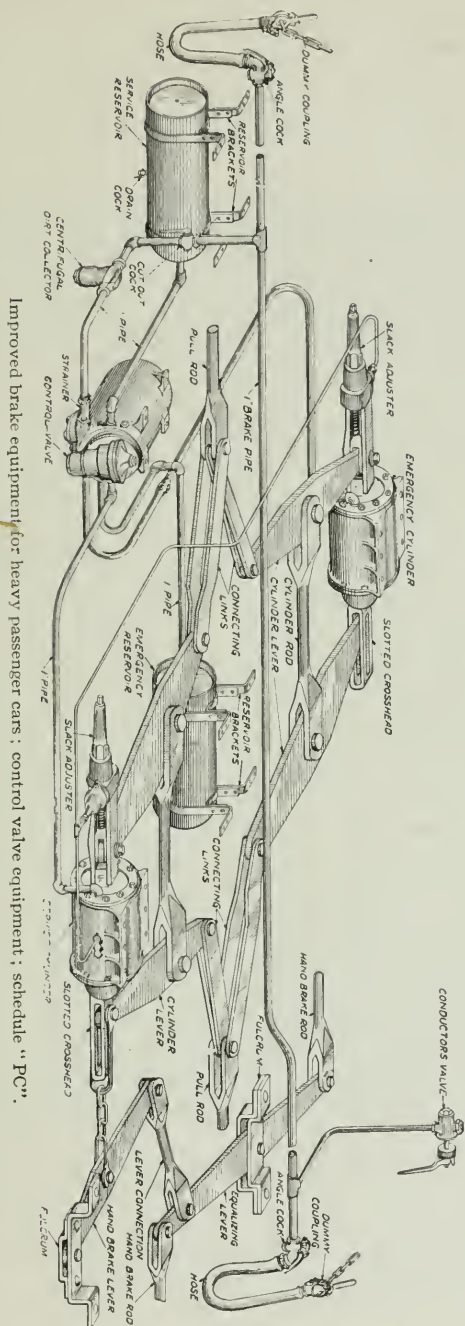
Fig. 20.

Improved brake equipment for heavy passenger cars; control valve equipment; schedule "PC".

12. Brake rigging designed for maximum efficiency.

13. Adaptability to all classes and conditions of service.

That certain of these requirements demanded radical changes in the valve device used on the car is evident from a comparison with the functions of the previous types already referred to, since but one of these required functions was contained in the older equipment. These considerations led to the latest development in the art of controlling heavy, high-speed passenger trains, employing what is known as a control valve in the place of a triple valve, the functions of which have already been mentioned in brief. The complete equipment is known as the schedule " PC " and is illustrated in Fig. 20.

The relative stopping power of the most efficient of the old order of brake apparatus—the High-Speed Brake—and of the control valve apparatus, is contrasted in the curves of Fig. 21. Both the comparative lengths of stop and the relative rates of rise and amount of maximum braking power are shown by the curves. It will be noted that the 575 foot shorter stop made with the " PC " equipment resulted not only from the higher braking power utilized but also from the quicker rate at which this braking power was built up to its maximum value. As a result you will note that the speed of the high-speed equipment train when passing the point (1100 foot stake) at which the " PC " equipment train stopped, was still as high as 38 miles per hour which means that 40 per cent. of its initial kinetic energy (at 60 miles per hour) still remained to be dissipated (harmlessly in this case, fortunately) before the train could be stopped.

Moreover, not only was this speed 38 miles per hour in the case of the high-speed equipment train, but it passed the 1100-foot stake 6 seconds before the " PC " equipment train reached that point. That is to say, the train with the " PC " equipment came to a stop at the 1100-foot stake 6 seconds after the train equipped with the high-speed equipment passed this point at a speed of 38 miles per hour. At the time when the " PC " equipment train stopped at the 1100-foot stake, the train equipped with the high-speed brake equipment was 275 feet further on, and still running at a speed of 28 miles per hour, which corresponds to a kinetic energy 22 per cent. of the original amount when the train was running at 60 miles per hour.

summary of development in passenger brakes.

From what has gone before, it will be seen that the existence and development of the passenger brake devices which have been described have come about, not spontaneously, of themselves, or
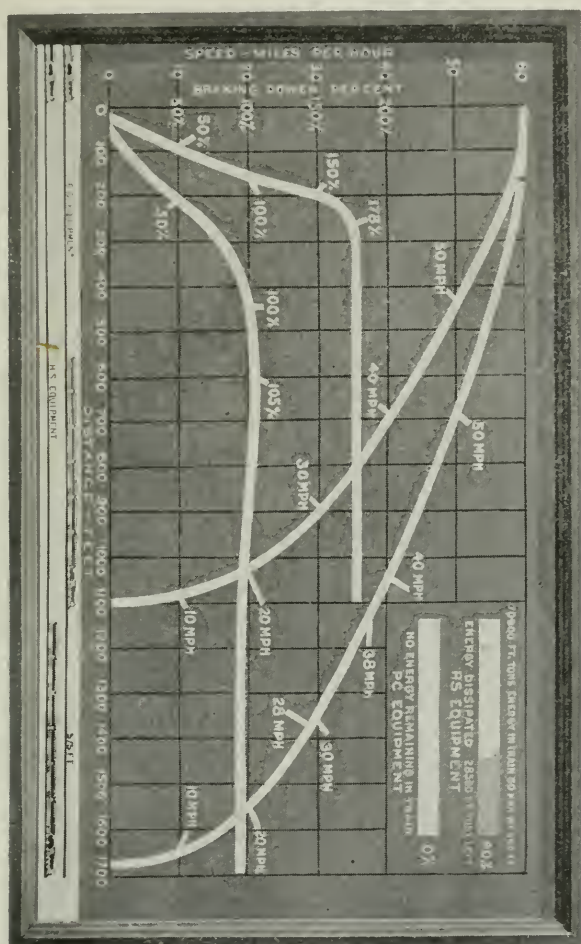
Fig. 21.

Comparative train stops, control valve and high-speed brake equipments.

solely for themselves, but in response to a definite need or for the purpose of accomplishing certain necessary and desired results, the end in view always being the safeguarding of life and property and increasing the facility, economy, and dispatch with which larger volumes of traffic can be handled.

Briefly, the conditions to be overcome and the objects to be attained may be summarized as follows:

CONDITIONS.—Increased weights of trains, greatly decreasing the relative efficiency of the brake and increasing the energy to be overcome in bringing the train to a standstill. Of two trains on the same number of wheels having the same nominal percentage of braking power, one being twice the weight of the other, the heavier train will run at least one-third further than the other.

Higher running speeds, increasing the energy to be overcome in making the stop in proportion to the square of the speed and adding directly to the length of stop according to the time required to obtain effective braking power on the train as a whole.

Greater frequency of trains, which increases the necessity for stopping quickly in a rapidly increasing ratio. Not only is it of more importance than ever that the trains be readily controlled within the distances between signals, but, with double- or four-track roads, there is the added greater possibility of the track on which the train is running being blocked by a break-in-two or other accident on the opposite track.

Increasing insistence upon the comfort and convenience of passengers and at the same time for greater economy in the handling of traffic, the latter being, in the nature of things, antagonistic to the former, without some special provision is made, looking to ultimate rather than circumstantial economy.

OBJECT OF IMPROVEMENTS.—*In Service Applications.*—(1) Much more flexible control of the train, greatly reducing possibility for shocks. (2) More uniform braking power, reducing surging in trains and flat wheels. (3) Uniform and maintained cylinder pressure notwithstanding variations in piston travel or leaky brake-cylinders. (4) Constantly recharged auxiliary reservoirs, which increase the safety to the highest degree. (5) Better protection against excessive braking power in service applications. (6) Shorter, smoother and more accurate stops.

In Emergency Applications.—(1) The human factor in the equation is reduced to a low point. (2) The increased percentage of braking power and prompt rise of brake-cylinder pressure compensates in a large degree for the decrease of the retarding force due to the increased work the brake-shoe now has to perform as compared with the old style brake. (3) Trains can be stopped in somewhere near the same distance as when

the cars were lighter.   (4) *Emergency Pressure is Available Even After a Service Application Has Been Made to an Extent Never Before Attained.*

<div align="center">EMPTY AND LOAD BRAKES.</div>

Under modern freight-traffic conditions, as already stated, uniformity of retardation on all cars in a train is second in importance only to safety.   This, with mixed loads and empties hauled in the same train, is inherently unobtainable with the type of brake considered thus far.   It can only be accomplished by providing means whereby a relative braking force more nearly comparable to that of the empty car can be utilized on the partially or fully loaded car.

The difference in braking power with the standard brake on loaded and empty cars would no doubt astonish anyone unfamiliar with the facts, but can be appreciated from the statement that the same brake-cylinder pressure which gives 60 per cent. braking power on an empty car will give only from 17 per cent. to 20 per cent. when this same car is loaded to its full capacity.

Four possible solutions are evident :

1. *Increased Brake-cylinder Pressure for a Given Reduction and on Equalization.*—In order to leave the braking power on the empties the same as at present but increase that on the loaded car to the desired amount, it would not be permissible to increase the brake-pipe pressure above the 70 pounds at present generally used.   Even if an increase above 70 pounds *for this purpose* were permissible, it would not give any higher braking power for ordinary service reductions, but only afford a higher equalization pressure.   An increase of reservoir volume, on the loaded car is therefore another alternative.   The maximum increase in pressure then available could not be greater than 70 pounds which, while only increasing the braking power on the loaded car by 40 per cent. (that is, from, say, 20 per cent. to 28 per cent. braking power) at the most, would destroy many fundamental and necessary features of the brake.   This is only about one-fifth or one-sixth of the increase required for a proper control of a car loaded to from two to four times its light weight.   This method is therefore impracticable.

2. *Increase the Total Leverage Ratio Temporarily on the Loaded Car.*—In the first place, the total leverage ratio for the

heavier modern freight cars and standard equipment is already
so high that any such increase as required by the loaded car
would be prohibitive. Aside from this, however, it has been
demonstrated by many repeated but futile attempts that none
of the various schemes thus far proposed for mechanically chang-
ing the leverage to correspond with the increase in car lading
(whether automatically with an increase of car weight or man-
ually) can be made practicable for actual road service. Once
established for the light car, the same leverage ratio must be
utilized for the loaded car.

3. *A combination of increased leverage ratio and auxiliary
reservoir volume* might be suggested as a possibility but it would
evidently combine the objectionable features of the first and sec-
ond alternatives just mentioned in such a manner as to aggravate
the undesirable effects of each. This method, therefore, fails
to afford the relief sought.

A fourth possibility remains, viz.:

4. *A Second Brake-cylinder to be Added to the Ordinary
Brake-cylinder to Control the Load.*—A number of equipments
of this type, of varying form, are being successfully operated on
a number of railroads, particularly in mountain grade service,
where the additional braking power thus provided is of advantage
in increasing the amount of tonnage handled in a given time down
the grade. It will be of interest to state, in outline only, the
characteristic features of forms which have proven successful.

1. Two brake-cylinders per car are used, one for the empty car
and both used together when the car is loaded to say two-thirds
or more of its rated capacity.

2. Standard leverage arrangement for the " empty " brake-
cylinder.

3. Suitable connections, take-up mechanism, levers, etc., to
form the connection and required multiplication of power from
the additional " load " cylinder to the " empty " cylinder lever
system.

4. Valve mechanism, in addition to that required by the
" empty " brake, for controlling the supply of air to and from the
added or " load " brake-cylinder.

5. Semi-automatic change-over valve-mechanism for cutting
the " load " brake in or out either manually or under certain
circumstances, automatically.

6. Additional reservoir capacity to furnish the air supply for the " load " brake.

The important problems entering into the operation of brakes on freight trains under present-day intensive traffic duty, for which the " empty and load " type of apparatus offers an ideal solution may be briefly stated as follows:

1. The necessity for more braking power on loaded cars than afforded by the ordinary form of brake, in order to increase the tonnage which can be handled down long or heavy grades with safety. Locomotives of such power are now built, that it is pos- sible, in some localities, to haul heavier trains to the top of the grades than can be safely controlled down the other side with the standard brake.

2. Trains of mixed loads and empties, especially long (50 to 100 cars) trains, where it is physically impossible or economi- cally impracticable to arrange the empty and loaded cars in the train to the best advantage, thus adding greatly to the danger of the train parting or damage to the lading and equipment due to inequality of braking power in different parts of the train, when the brake is applied at some critical speed or locality.

3. Locomotives of great weight, but relatively low braking power, tending to increase the internal stresses in the train due to unequal retardation on diffrent cars in the train.

4. The advent of large capacity cars, aggravating the differ- ences in retardation due to lading, so that the percentage of brak- ing power on such cars, when loaded, is reduced to a greater extent than on cars of lower capacity, for which the proportion of loaded to light weight is less.

5. The requirement of operating both short and long freight trains with practically all air-brakes cut in. This, on a long train, with loads ahead and empties on the rear end, presents an operating problem difficult of solution with the old standard brake.

PRINCIPLES OF TRAIN BRAKING AND BRAKE DESIGN.

Throughout the foregoing description of the development of the various types of brake apparatus, occasion has been taken to explain at the same time the operating conditions and service requirements responsible for their being. While this has neces- sarily involved some reference to some of the fundamental prin- ciples underlying the proper application and operation of brakes

as related to convenience, economy and safety in train control, there are certain limiting conditions and fixed laws which should be treated more specifically and in detail. This is not so much because the present state of the air-brake art exemplifies the application of these laws and principles to the complex demands of modern freight and passenger service, but rather because it is only by a careful study and sound working knowledge and appreciation of the significance of these laws that anyone is able to judge positively and accurately, on the one hand, the adaptability of, or necessity for, any new air-brake device, and on the other, what are the requirements to which any new device or method must conform in order to adequately and efficiently satisfy the requirements of new service conditions.

STARTING AND STOPPING.

The problems of deceleration, retardation and the flexible control of trains must receive more and more attention from a scientific and technical stand-point, in order that to-day theory and practice may be combined to produce the best results in the shortest time. This is necessary if the brake is to efficiently and satisfactorily meet the wonderfully changed conditions which have developed since the invention of the quick action, automatic brake. The high speeds and great weights of the present day requiring that advantage be taken of every opportunity offered to increase and flexibly control braking power.

Starting and stopping of trains are complementary factors in the problem of making time between stations, therefore it is evident that the best results can only be obtained where both factors are given due consideration. Generally, the starting factor is the only one fully considered, or, at least, the one more fully provided for, and this notwithstanding that better results can be obtained if both are considered and the more efficient brake system installed.

In another sense, the question of stopping is the most important, as the safety of the service and the freedom of delays to a great degree depend upon it. The measure of the value of the brake is two-fold,—(1) the ability to stop in the shortest possible distance when necessary; and, (2) to permit short, smooth and accurate stops being made in regular operation. Therefore both these factors should be considered when design is under way.

Fig. 22.

CLASS E-2-D LOCOMOTIVE.

TOTAL WEIGHT OF TRAIN	559.6 TONS.
ACCELERATION	DISTANCE OF 18500 FEET
TIME OF ACCELERATION	5 MIN. 47 SEC.
DECELERATION	DISTANCE OF 954 FEET.
TIME OF DECELERATION	18.7 SEC.

TOTAL ENERGY STORED IN TRAIN AND OVERCOME BY BRAKE 63250 FOOT TONS

DISTANCE IN THOUSAND FEET
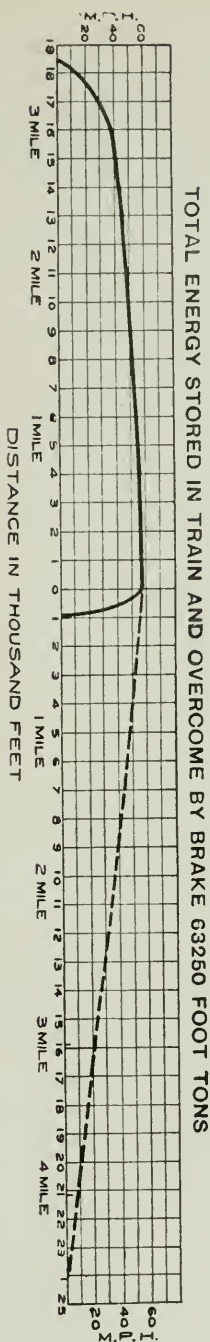
BROKEN LINE REPRESENTS STOP WITHOUT THE USE OF BRAKES.

NOTE:- THE CALCULATED STOP WITHOUT BRAKES WAS OBTAINED BY ASSUMING 9.6 POUNDS PER TON RETARDATION DUE TO WIND RESISTANCE AND JOURNAL FRICTION. TRACK LEVEL.

Acceleration and deceleration curves; Absecon tests.

Unfortunately, the brake is usually looked upon as a safety device only, and it is because of the prevalence of this idea that its installation and maintenance do not receive the consideration merited. Considering the investment, there is no part of the rail way equipment that will give greater material returns than the brake when properly installed, operated and maintained. If the brake could to some extent be separated from the idea or im pression that it is a safety device only and proof advanced to show that it makes possible the hauling of heavier cars,—in fact, makes the heavy car possible,—that it makes possible, faster and more frequent service,—as much or more than does the locomo tive, the block signal and the good roadbed,—and that, if given the consideration it should have, it would increase the possibili ties, profits and value of all these things,—its importance would be more fully appreciated and, therefore, at least the same consid eration be given to its design and installation that is accorded to other parts of railway equipment. A safety device, the brake is, par excellence; but it has other reasons for its existence.

Very few, perhaps, realize that the brake under a single car is much more powerful than the locomotive that pulls the train, yet this will be apparent to any who examines the records of a dynamometer car alone attached to an engine, the stops being made by brakes on the dynamometer car. Few realize that it takes a locomotive perhaps five minutes, perhaps ten minutes, and a distance of some miles,—six or seven,—to attain a speed of sixty miles per hour. Imagine the condition of affairs which would exist if it took a brake that length of time and distance to stop the train. The comparison is somewhat startling, but it is only because the condition is one of those commonplaces which have been taken for granted so long that they are accepted as in herent rather than being given the degree of consideration which their significance warrants. Fig. 22 is an illustration of the facts stated, taken from the records of a run during a series of tests at Absecon, N. J., 1907, the train being composed of a locomotive and ten cars. What it took the locomotive nearly six minutes and a distance of about three and a half miles to accomplish was overcome by the brakes in less than twenty seconds and within a distance of about one thousand feet. The broken line repre sents what the stop might have been if no brakes had been used, *i.e.*, the train brought to rest by the resistance of the air. and

journal friction.   All of the elements so strongly contrasted in
Fig. 22 are familiar in themselves but their reciprocal relationship
is often overlooked.   The average passenger train of to-day can
be stopped from a speed of sixty miles per hour in about twenty
seconds' time.   To build a steam locomotive that would accelerate
a train in the time and distance that the brake stops it, would be
impossible, for in order to have the necessary adhesion to the rails,
which would permit of developing the required drawbar pull,
the steam locomotive would have to weigh approximately twice
as much as the train itself, which is, of course, prohibitive.   Elec-
tric locomotives, however, are no longer to be regarded with
uncertainty or as mere experiments and there is every reason to
believe that the electric locomotive will be able to accelerate a train
to a speed of sixty miles an hour in certainly not more than a
minute and a half, and probably not more than one minute's
time.   That means that the brake is going to be even *more*
important in the future than it has been in the past.   In propor-
tion as we accelerate, we must perforce be prepared to decelerate.
The ability to accelerate, or even to run at high speeds, must be
measured by the ability to stop.

    As an example, however, of how little this is appreciated such
a question as the following is often asked and a categorical answer
apparently expected: " In what distance should a train be
stopped from a speed of fifty miles per hour? "   Perfectly simple,
isn't it?   Here we have one known factor, from which we are
expected, apparently, to derive all the other factors which are of
equal importance and must be known before an answer of any
value can be given to such a question.   A few of these factors
are: the light weights and loads of the vehicles composing the
train; the percentage of braking power used with engine and
cars; whether or not all wheels, including truck and trailer (if
any), of the locomotive were braked; what type of brake equip-
ment was used; what pressures were carried; whether the train
was accelerating or decelerating; on a curved or straight track;
on an ascending or descending grade, or level; the condition of
the rail; whether the brakes were applied in service or emergency,
or ordinary service and then emergency; the piston travel on each
vehicle; the losses to friction of parts, brake-beam release
springs, etc.; wind resistance; quality and thickness of brake
shoes and method of hanging them, for this affects materially the
efficiency of the brake, both as to absorbing power and lengthen-

ing the piston travel which reduces the pressure otherwise obtainable. Furthermore, it should by no means be understood that the precise effect of each of these could be accurately calculated, even though full information were at hand, and a little thought will make it evident that each of the factors mentioned above may have a considerable influence on the length of the stop.

These things are merely mentioned to emphasize the great importance of the air-brake and the necessity for considering carefully what principles govern its action. It does not make very much noise. It does not occupy so prominent a place in the papers as electricity, for instance; yet it has been much more of a factor in railroad development up to the present time than electricity.

I may be pardoned for asking you to form a comparison between the propelling and stopping mechanism of our steam rail-roads. The locomotive is much in evidence, being large and of powerful appearance and placed in the most conspicuous place in the train. The brake is, outwardly, a comparatively insignificant piece of apparatus, installed on the different vehicles of the train; placed underneath the cars where it is hard to find, and seldom observed by the traveller. The very fact that it is so distributed over the train is one reason for its power and efficiency. When we realize the forces handled by the two devices, and the great difference in point of time in which their work is accomplished, our respect for the brake will be stimulated, since it *must* be capable of dissipating the energy, stored by the locomotive in the train, in but a fraction of the time required by the locomotive to do this, if the safety of transportation is to be preserved.

FUNDAMENTAL PRINCIPLES IN BRAKE DESIGN.

In the establishment of a logical basis of brake design, applicable to the conditions under which brakes in general must operate and involving a determination of the essential elements of an elementary brake system for any given car, the starting point must be the light weight of the car. Fortunately this can usually be determined in advance to any desired degree of accuracy. For convenience, suppose the car to be fully equipped with a complete brake equipment and by an analysis of the factors involved in stopping the car, determine how these factors may best be provided for in the design.

Assuming that the wheels do not skid, the actual *braking force* acting on a car when the brakes are applied is the force of the friction between the brake-shoes and the wheels, tending to retard the rotation of the wheels and thus stop the car.   The relation which this bears to the energy stored up in the moving car, provided the " adhesion " of the wheel to the rail is not exceeded, determines the effectiveness of the brake and the length and time of stop.   The energy of the moving car consists of two parts—that of the car as a whole due to the velocity of translation, and that of the revolving wheels, due to their rotation, and varies as the weight of the car and as the square of its velocity.

The latter may roughly be taken as 5 per cent. of the energy of translation for 12-wheel cars and as 2 per cent. of the energy of translation for 8-wheel cars.   In ordinary calculations, however, this factor is usually neglected, and properly so, because for modern rolling stock the resistances other than as derived from the brakes, such as internal friction, air resistances, flange friction and so on, has been shown by actual experiment to at least equal if not exceed the inertia effect of the revolving parts.   Consequently a greater error is made by considering the energy of rotation without at the same time taking into account the resistances to motion which exist due to other causes than the brake-shoes (which, it should be noted, are usually indeterminate and subject to considerable variation) than to assume that these two opposing factors neutralize each other.

The frictional force between the brake-shoes and wheels depends on the pressure acting on the shoes and the coefficient of friction between the shoes and the wheels.   In making a stop, therefore (it being assumed throughout that the wheels do not skid), the factors involved, so far as retarding the rotation of the wheels is concerned, are :

1. The total amount of brake-shoe pressure in pounds, commonly called the " braking power."

2. Coefficient of friction between the shoes and the wheels, by which the brake-shoe pressure must be multiplied in order to determine the actual retarding force.

3. The weight resting on the wheels.

4. The velocity of the car.

5. The rotative energy of the wheels.

Only one of these factors can be controlled even partially in service or fixed arbitrarily in designing the brake system, viz.,

the pressure on the brake-shoes. Inasmuch as the wheels must not skid when the weight resting on the wheels is least,—that is, when the car is not loaded,—the light weight of the car must be taken as the basis of calculation regarding brake-shoe pressure, except in the case of some form of " empty and load " brake. Since the " braking power " is, by custom, measured by a scale of percentages wherein 100 per cent. represents a shoe pressure on each wheel equal to that wheel's pressure on the rail, the problem is then to determine and insure the obtaining of the proper relation between the brake-shoe pressure and the light weight of the car.

As pointed out above, the factors involved, such as frictional coefficients, speed, weights, etc., are so subject to variation in service that no theoretical conditions can determine the proper nominal percentage braking power (*i.e.,* the ratio of brake-shoe pressure to light weight of car), which shall best meet average road conditions. This can be fixed only by experiment and experience and is subject to modifications as conditions change or become more thoroughly understood. For example, many years' experience has proven that 90 per cent. braking power for passenger cars gives satisfactory braking effects with a reasonable margin against wheel sliding and sufficient power for service stops. This was determined by the results obtained on the lightest cars. So far as wheel sliding is concerned, a 150,000-pound car braked at 95½ per cent. has practically the same margin against wheel sliding as a 70,000-pound car braked at 90 per cent. But if the percentage of braking power is varied, the uniformity of service braking effect, other factors being the same, is lost. *Therefore, the percentage of braking power determined as a satisfactory maximum for the lightest cars* must be adhered to on all cars, in order to bring about as nearly as possible the uniform results which are necessary for satisfactory service operation.

Having, therefore, chosen a certain percentage of braking power which should be obtained on all cars, it is evident that what actually is obtained, in any given instance, depends on the total leverage ratio and the pressure per square inch on the brake-piston. It will be apparent that all resistances between the brake-piston and brake-shoes, such as release springs, reactions of hanger links, friction of rigging, etc., must necessarily be ignored until the essential factors in the design are determined upon.

The total leverage ratio is fixed within certain limits by purely mechanical consideration, with regard to piston travel, shoe

Chart showing relation between size of brake-cylinder, brake-cylinder pressure, total leverage ratio, braking power, and weight of car.
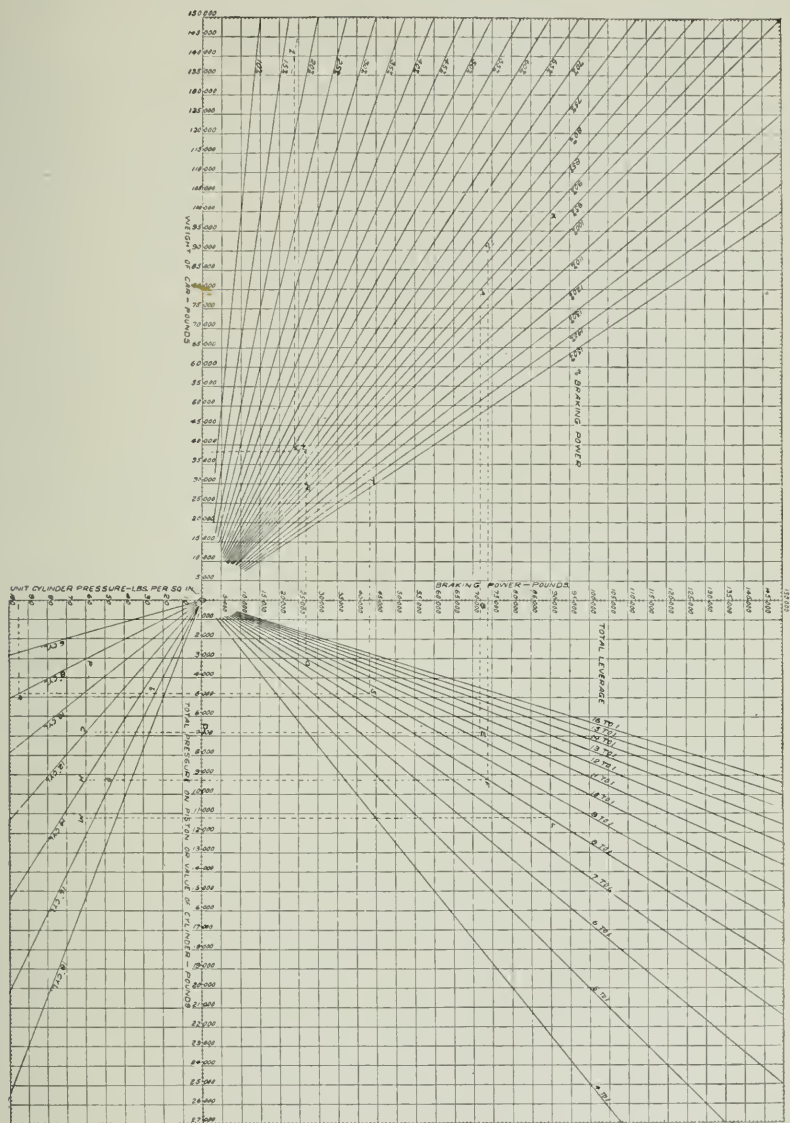
Fig. 23.

clearances, etc., and once the foundation brake rigging is designed, remains always the same.

Hence in any given case the percentage of braking power actually obtained depends entirely on the pressure existing in the brake-cylinder, which varies in practice from zero to the maximum obtained when an emergency application is made.

In designing the brake system for a car, therefore, the leverage ratio and size of brake-cylinder must be so proportioned as to give the required braking power in pounds, with some arbitrarily chosen pressure in the brake-cylinder. Evidently this braking power will be obtained in practice when the brake-cylinder pressure is that on which the design of the brake system was based. For any pressure lower or higher than this, the braking power, in pounds, will be correspondingly lower or higher than the nominal. Furthermore, the actual percentage of braking power (ratio of brake-shoe pressure to weight on wheels) varies not only with the brake-cylinder pressure but also with the condition of the car,—whether loaded or empty.

From a consideration of these conditions it seems evident that it is practically impossible to provide for even an approximate uniformity of brake action on different cars in service by any method of design. The best that can be done is to establish and adhere strictly to the assumed standards upon which such designs are based.

1. The " percentage of braking power " in terms of the light weight of the car.

2. The brake-cylinder pressure upon which this percentage is based.

The former, as has already been stated, must be determined from experiment and experience. The latter must be chosen arbitrarily, but it should have the same value for all brake calculations, in order to insure a common base being universally used and understood. Fig. 23 graphically illustrates the relations existing between these two factors for different weights of cars and total leverage ratios. The question now is, therefore, " What brake-cylinder pressure should be used as a basis in designing the brake systems of all types and classes of cars? "

With a given auxiliary reservoir charged to a standard pressure, and with a given brake-cylinder having standard piston travel, a certain definite pressure of equalization is obtained, which is constant so long as the other factors involved are kept constant.

When an emergency application is made, since a portion of

the air in the brake-pipe or other source of supply is used in addition to that in the auxiliary reservoir, the resulting brake-cylinder pressure is augmented in proportion, and a higher maximum pressure therefore obtained.   Evidently its value must depend upon the relation which the supplementary brake-pipe volume bears to that of the auxiliary reservoir and brake-cylinder combined.   With equipments now in general use this ratio must necessarily decrease as the size of the car increases because the brake-pipe volume remains practically constant for all sizes of cars, while the brake-cylinder and auxiliary reservoir volumes increase as the size of the car increases.   It then follows that where air from the brake-pipe alone is used to augment the brake-cylinder pressure in emergency applications, the emergency pressure thus obtained must vary with the different combinations of auxiliary reservoir and brake-cylinder necessary for different sizes of cars—the gain in pressure from this source over that obtained in full service equalization being greatest with the smallest sizes of auxiliary reservoirs and brake-cylinders.

Hence, in choosing a brake-cylinder pressure on which to base brake calculations, that obtained in emergency, which was satisfactory where the brake-cylinders were of such size that a uniform pressure was obtained in both service and emergency, is now excluded at the outset,—from the stand-point of uniformity,—since in the nature of the case it is not uniform for all weights of cars.   This is for the reason that brake-cylinders may vary from 6 inches to 18 inches diameter with correspondingly varying pressures in emergency.   And if the braking power desired is based on a brake-cylinder pressure higher than can actually be obtained, then for lower cylinder pressures the brake is not so effective as it might be made, were the braking power based on the pressure actually obtained.   The smaller cars which do obtain this pressure, give the calculated braking power in emergency, but the heavier cars cannot, and there is a loss, both in uniformity of emergency action and possible efficiency.

On the other hand, for brake-pipe reductions less than sufficient to produce equalization, the cylinder pressures obtained are uniform, provided the other factors are uniform in value and the pressure at which the auxiliary reservoir and brake-cylinder equalize is supposed to be the same for all combinations of reservoirs and cylinders, with the same initial pressure.   To obtain this uniformity it is only necessary to properly proportion the

reservoir volume to the brake-cylinder volume for some standard piston travel. We then have a pressure base which will be constant when the other factors involved have their proper or standard values. It would seem that this is the basis to which all braking power calculations should be referred, for the reason that it is the nearest approach to a uniform and constant pressure obtainable under the wide range of conditions governing this choice. This adds to the standard enumerated on the preceding page, the following:

3. This brake-cylinder pressure must be the equalized pressure on the auxiliary reservoir and brake cylinder.

4. A predetermined ratio between auxiliary reservoir volume and brake-cylinder volume to produce this equalization must be adhered to.

The fundamental steps in designing a brake system for any given car may now be outlined as follows:

Given the light weight of the car the proper braking power per cent. has been established from results of experiment and experience and this enables the total brake-shoe pressure to be calculated.

Mechanical considerations fix the total leverage ratio between certain limits, the maximum and minimum values of which enable a maximum and minimum total brake-piston pressure to be calculated from the preceding.

This total brake-piston pressure depends upon the size cylinder and pressure per square inch used as a basis. The pressure basis to be used should be that agreed upon as a universal standard, for such calculations as this, and, as has already been pointed out, uniformity requires that the *equalization pressure* (50 pounds per square inch), from the lowest standard brake-pipe pressure carried, should be the base chosen.

Having determined the unit pressure, the size of cylinder can be chosen from the standard sizes manufactured to give the desired braking power with a total leverage within the maximum and minimum limits as defined above.

To obtain the desired 50 pounds equalization pressure from the standard 70 pounds brake-pipe pressure with a standard piston travel, is simply a matter of correctly proportioning the auxiliary reservoir volume to that of the brake-cylinder at the piston travel employed as standard.

We then have an auxiliary reservoir which, at 70 pounds in-

itial pressure, will equalize with its brake-cylinder, when this has eight inches piston travel, at 50 pounds, and the brake-cylinder piston is of such an area that the total pressure thus obtained, when multiplied by the total leverage, will give a total brake-shoe pressure equal to the desired percentage of the light weight of the car.

To be sure, in an emergency application, the braking power on all cars will be greater than that used in the design, and the lighter the car the greater the variation between service and emergency braking powers. But such non-uniformity in actual service is bound to obtain, and always has, since an increase to 90 pounds brake-pipe pressure, or a variation in piston travel produces similar results, to say nothing of losses due to leakage, resistances and variations in frictional coefficients. The advantage gained, however, by the method of design outlined is, therefore, in the fixing of a uniform and actually obtainable brake-cylinder pressure, which is necessary for service operations and is one of the most important factors in the calculation to be made.

It may be said in passing that with the more recent types of brake-equipments for passenger service, using a supplementary reservoir volume, in addition to that of a brake-pipe to produce high emergency brake-cylinder pressure, the size of supplementary reservoir used is calculated to give practically uniform brake-cylinder pressures in emergency applications with *all* sizes of brake-cylinders, thus taking advantage of the principle of high pressures for emergency stops and at the same time conforming to the principles of uniformity laid down above, it being a fundamental principle of modern brake design to keep the service equalization brake-cylinder pressure comparatively low, for reasons fully explained elsewhere, and use as high an emergency equalization pressure (as large a supplementary reservoir), as may be desirable.

In the attempt to secure a high emergency brake-cylinder pressure without the aid of the supplementary reservoirs referred to above, the relationship between brake-cylinder and auxiliary reservoir volumes existing in the *original* brake design was gradually lost; the auxiliary reservoir volume being increased slightly, from time to time, as heavier cars, requiring larger brake-cylinders, were equipped. On the lighter equipment the variations thus introduced were relatively unimportant, but in the case of heavy cars, requiring the 16-inch and 18-inch cylinders, it was im-

possible to increase the auxiliary reservoir volume sufficiently to obtain the desired emergency pressure, without at the same time interfering to a marked degree with the proper operation of the equipment in service. Consequently, a compromise was made, so as to obtain as high an emergency cylinder pressure as possible without increasing the service equalization pressure to an extent inconsistent with the proper normal functions of the brake.

By the aid of a supplementary reservoir volume, however, reserved during service operation, but available in emergency applications of the brake, it is now possible to obtain the required increase in stopping power for emergencies and at the same time return to the original volume relationship, the correctness of which has been established by long experience.

These relationships are determined by the following principles, which will be recognized at once as having been followed in even the earliest automatic-brake designs.

(A) For any given arrangement of leverage between the brake-cylinder piston, and the brake-shoes, the " braking power " is directly proportionate to the gage pressure of air produced in the brake-cylinder.

(B) The limitation of the maximum allowable pressure of air in the brake-pipe limits thereto the available pressure in the auxiliary reservoirs.

(C) With this fixed maximum charge in the auxiliary reservoir, the highest pressure obtainable in the brake-cylinder from this single source is that at which the air pressure equalizes between the two. This (absolute) pressure, therefore, equals the product of the initial absolute pressure in, and the volume of the auxiliary reservoir divided by the sum of, the volumes of the auxiliary reservoir and of the brake-cylinder (neglecting all clearance volume, temperature effect, etc.), and the " braking power " is as the corresponding gage pressure.

(D) This pressure of equalization should be limited because its height determines the range of those differences between final auxiliary reservoir pressure and initial brake-pipe pressure, which range affords the control of " braking power " applied.

(E) That while low pressure of equalization limits " full service " pressure, yet small range precludes nicety of control, especially as from the range there must be deducted such initial differences of pressure as are necessary to overcome the inertia and friction of the triple valve parts.

(F) That to afford heightened brake-cylinder pressure for use in emergency another quantity of air is necessary, and if this be, as in all past practice, that contained in the brake-pipe, the resulting absolute pressure will be equal, theoretically, to the maximum absolute brake-pipe pressure multiplied by the volume of the auxiliary reservoir plus the amount of air, in cubic-inch-pounds, obtained from the brake-pipe, this sum then divided by the volume of the auxiliary reservoir plus that of the brake-cylinder, so that the measure of the resulting braking pressure is the gage pressure corresponding to this resulting (absolute) pressure.

Now, it is the interdependence and reactive results of these simple and recognized principles in their combinations together with a corresponding proportioning of leverage between the brake-cylinder piston and the brake-shoes that determine the relative efficiency of a brake design.

From (F) it is seen that if other parts be enlarged the volume of the break-pipe, which is practically the same on all cars, becomes relatively small and the emergency pressure sought is so insufficient that in the equipments for heavy rolling stock resort has been had to enlarged auxiliary reservoirs with a correspondingly heightening of the " full service " pressure (C), and a resulting lessening of the range of control (D).

Again when (C) is heightened while (D) is lowered, the results of the lighter brake-pipe reductions cause magnified effects in the service braking, so that, when it is realized that such range as is possible is lessened by the lack of sensitiveness of the triple valve (E), there is likelihood of roughness of service stops.

Such being the case, it is apparent:

1. That there is a ratio of volume of auxiliary reservoir to that of brake-cylinder that should not be exceeded.

2. That such service pressures as result in the brake-cylinder should be made sufficient by a corresponding proportioning of the leverage.

3. That the volume of each car's part of the brake-pipe should be supplemented by proper means so as to afford the required braking pressure in emergency.

Starting, therefore, with a brake-cylinder of the size *dictated* by the vehicle to be equipped, as already explained, and by a proportioning of the leverage which shall accord with the service required, and assuming that

C equals volume of brake-cylinder, in cubic inches ;
P equals service equalization pressure, in absolute units ;
R equals volume of auxiliary reservoir, in cubic inches ;
a equals absolute initial pressure in the auxiliary reservoir ;
r equals permissible range of brake-pipe reductions ;

it follows first, from the above definitions, that

$$r = a - P$$

and from (C) above, neglecting clearance volumes :

$$\frac{a \times R}{R + C} = P$$

from which

$$R = \frac{P}{a - P} \times C$$

$$= \frac{P}{r} \times C$$

which may be expressed in the following law :

The proper auxiliary reservoir volume, according to the principles laid down above, is equal to the volume of the brake cylinder determined upon multiplied by the ratio of the service equalization pressure fixed upon as standard to the permissible range of brake-pipe reductions.

Assuming, as in current practice, that P equals 50 pounds per square inch (gage) and a equals 70 pounds per square inch (gage), then we have

$$r = a - P = 20 \text{ pounds,}$$

and

$$R = \frac{P}{r} \times C$$

$$= \frac{65}{20} \times C$$

$$= 3\tfrac{1}{4} \times C.$$

That is, the volume of the auxiliary reservoir should be three and a quarter times the volume of the brake-cylinder. It is plain, however, that the effect of the clearance volumes, leakages, temperature, and other adverse influence will be such that to obtain the desired results in actual service a somewhat higher auxiliary reservoir volume must be used than that found by the above calculations. For example, with the standard 8-inch equipment, an auxiliary reservoir volume of 1620 cubic inches is used, which is about three and one-half times the brake-cylinder volume.

In determining the proper size of supplementary reservoir

(F) to be used a similar reasoning may be used.   In addition to the symbols already defined, let

$S =$ volume of supplementary reservoir in cubic inches.
$E =$ absolute emergency equalization pressure.

Assuming for the purposes of calculation that the emergency pressure is the result of the equalization of the brake-cylinder, auxiliary reservoir and supplementary reservoir volume, it follows that

$$\frac{a\,(R+S)}{R+S+C} = E,$$

whence, by proper substitution and reduction, is derived

$$S = \frac{a\,(E-P)}{r\,(a-E)} \times C.$$

While the above expression is interesting as showing the simple relation which exists between the various volumes involved in the typical equipment as we have assumed it, it must be clearly understood, first, that all the additional air supply in emergency is supposed to come from the supplementary reservoir, having taken no account of that vented from the brake-pipe; and second, that in any actual installation similar to that discussed, the equalization is dependent upon the movement of certain valves actuated by spring and air pressures in combination, the resultant effect of which is such that in the actual working equipment the state of affairs is by no means as simple as has been assumed for the typical equipment.   Instead of equalization taking place between all the volumes concerned simultaneously, there are time limitations imposed on the rate of flow from the various sources of air supply to the brake-cylinder, so as to derive the maximum possible benefit from the compressed air stored in each.   There is also a material modification of these calculated results, due to the processes not being truly isothermal, as assumed, and so on. Proper allowance being made for these limitations, a formula might be derived, in the same manner as above, to completely cover the more complicated conditions, but as only the principles involved are now being considered it is unnecessary to go further into details, particularly as these are accurately determined by experiment.

In the above analysis, as is necessarily the case with all theoretical considerations relative to mechanical apparatus of this character, certain assumptions were made to furnish a basis from which to start.   Hence, it should always be remembered that the

formulæ derived must be interpreted, for any given case, in the
light of the modification of these primary assumptions which the
nature of the installation or the character of the apparatus used,
may involve. With this understanding, the above reasoning
affords a logical and sound theoretical basis, not only for deter-
mining the correct proportions of new types of equipment, but
also establishes a criterion, by means of which the shortcomings
of incorrectly designed installations may be discovered.

BRAKES FOR ELECTRIC TRACTION SERVICE.

It would hardly be proper to conclude without mentioning the
fact that the electric traction service has required even more
specialized apparatus than that already mentioned in connection
with steam-road service on account of the great variety of condi-
tions under which electric cars operate from the single city street
car up to the 8- and 10-car subway and elevated trains, to say
nothing of the electric locomotive and multiple unit train service
on electric division or steam railroads. It can easily be appreci-
ated that these phases of the subject are of even greater magnitude
and requires a greater variety of apparatus and complexity of de-
tail than in the case of steam-railroad service. Consequently, no
more can be said at this time than to simply state the fact that
the multiplicity of requirements has been anticipated and provided
for to the extent that the high standard of efficiency already out-
lined to you has been maintained without any compromise or
failure to meet the requirements of the service. In one particu-
lar, at least, the highest type of brakes, for electric service,
namely, the Electro-Pneumatic System, affords superior stopping
power and service efficiency, since its electric transmission of
quick action insures simultaneously and almost instantaneously
maximum braking power on all cars in the train, while for service
braking, it possesses the maximum flexibility of control, possible
only in an electrically actuated brake system. This brake there-
fore possesses superior features which are particularly note-
worthy whether they are considered from the stand-point of the
time saved, the increased traffic made possible, or the safety in-
sured. At the present time, this type of equipment appears to be
the acme of the braking art, but as past experience has always
shown, the same time which brings about changes in operating
conditions is also sure to develop new and more efficient means
for meeting new requirements.

APPLICATIONS OF CHEMISTRY TO PUBLIC WELFARE.

BY

HARVEY W. WILEY.

PRESIDENT CLARK, MEMBERS OF THE INSTITUTE, LADIES AND GENTLEMEN : I desire to express my sincerest thanks to the Franklin Institute for the high honor conferred on me. I feel that it is a recognition of the value of the work I have tried to do during the past quarter of a century rather than a personal honor, and therefore it is shared by my faithful assistants without whose help this work could not have been accomplished. I accept the medal and diploma which have just been given, and in doing so it is my duty to set forth briefly some of the salient features of the work for which this signal recognition has been given.

Science is knowledge of the knowable; faith is knowledge of the unknowable. Science is exact, that is, quantitative when it is possible that our knowledge of any subject shall be quantitative knowledge; science is inexact when it is qualitative, that is, when our knowledge of a subject is not definite. Mathematics, astronomy and chemistry are quantitative sciences in that the data on which they are based are capable of exact measurement. Biology is to a certain extent a qualitative science in that our knowledge of it in the very nature of things cannot be exact. A theory must not be confounded with a fact. Theories to be of value must be produced either by a scientific imagination which can look into the unknown and see the relations of things to a certain extent and thus be able to predict properties of bodies or forces yet undiscovered, or a theory may be retrospective, based upon accumulated facts and, reasoning by induction therefrom, explain still other facts that are yet undetermined with exactitude.

Science has often been subdivided into the pure and the

applied, but this subdivision it seems to me is untenable and discriminative. What is known as pure science will perhaps be better designated as unused science, if any science could be deemed as unused; applied science, on the other hand, might perhaps be better named as used science if this designation may be made. In point of fact there is no dividing line between science as such, or potential science, and science in action, or dynamic science. It is inconceivable that any expression of fact or truth could fail of being useful in some way or at some time and therefore the pursuit of knowledge of all kinds when properly prosecuted must end in useful discoveries.

In the application of science to agriculture we have combined both the discovery of new truth and the application of old and new truth. Theories are of little consequence aside from their convenience of classification and arrangement. A man's theory of nature does not affect nature in the least, nor does it have any effect upon natural processes. The aurora borealis exists whether it be due to electrical effects, high rarification or any unexplained emanations, and the procession of the equinoxes continues to change the actual point of the pole irrespective of the theories of what is supposed to produce it. Crops continue to grow regardless of what the theories of plant nutrition may be, and variations continue to be naturally produced in animals and plants irrespective of the theories of heredity or evolution.

In the work over which I have had the honor to preside in the Department of Agriculture, for almost thirty years, we have been troubled very little by theories—we have been confronted always with conditions. The investigations which have been made, therefore, have not been to establish any preconceived notions, but to ascertain as nearly as possible facts in regard to the production of phenomena under observation. One of the first investigations undertaken in the realm of agricultural science was a study of the conservation of and waste of plant food. Long before the present vogue of conservation came into existence we planned and executed important studies in the conservation of plant food. These studies were crystallized in two addresses which I gave, one in 1886 as Vice-President of the Chemical Section of the American Association for the Advancement of Science, on " The Economical Aspects of Agri-

cultural Chemistry," and another as the retiring President of the American Chemical Society in 1893, on " The Waste and Conservation of Plant Food." In the summary of the data in the address on the economical aspects of agricultural chemistry the following statements are made :

Future Food Supply.—Since, with a proper economy, the natural supplies of potash and phosphoric acid, as we have seen, may be made to do duty over and over again, and last indefinitely, the economist who looks to the welfare of the future need have no fear of the failure of these resources of the growing plant. Indeed, it may be said that the available quantities of them may be increased by a wise practice of agriculture based on the teachings of agricultural chemistry.

But with the increase of population comes an increased demand for food, and therefore the stores of available nitrogen must be enlarged to supply the demands of the increased agricultural product. It is certain that with the new analytical methods, and the new questions raised by the investigations of which I have spoken, many series of experiments will be undertaken, the outcome of which will definitely settle the question of the entrance of free nitrogen into vegetable tissues. If this question be answered affirmatively, agricultural science will not place bounds to the possible production of foods. If the nitrifying process does go on within the cells of plants, and if living organisms do fix free nitrogen in the soil in a form in which at least a portion of it may be nitrified, we may expect to see the quantities of combined nitrogen increase *pari passu* with the needs of plant life.

Thus even intensive culture may leave the gardens and spread over the fields, and the quantities of food suitable for the sustenance of the human race be enormously increased. In regarding the agricultural economies of the future, however, it must not be forgotten that a certain degree of warmth is as necessary to plant development as potash, phosphoric acid, and nitrogen.

If it be true, therefore, that the earth is gradually cooling, there may come a time when a cosmic athermacy may cause the famine which scientific agriculture will have prevented.

Fortunately, however, for the human race, the cereals, the best single article of food, are peculiarly suitable to a cold climate. Barley is cultivated in Iceland, and oatmeal feeds the best brain and muscle of the world in the high latitudes of Europe.

It is probably true that all life, vegetable and animal, had its origin in the boreal circumpolar regions. Life has already been pushed half-way to the equator, and slowly but surely the armies of ice advance their lines. The march of the human race equatorwards is a forced march, even if it be no more than a millimetre in a millennium.

Some time in the remote future the last man will reach the equator. There, with the mocking disk of the sun in its zenith, denying him warmth, flat-headed and pinched as to every feature, he will gulp his last mite of albuminoids in his oatmeal, and close his struggle with an indurate inhospitality.

In the closing paragraphs of the address on the waste and conservation of plant food, I say:

> Through the ages of the past, the rich stores of plant food have been steadily removed from arable fields and apparently forever lost. But in point of fact no particle of it has been destroyed. Even the denitrifying ferments described by Springer, Gayen and Dupetit, and Muntz, reduce only to a lower stage of oxidation or restore to a gaseous form the nitric nitrogen on which alone vegetables can feed. But electricity, combustion, and the activity of certain anaerobic ferments herding in the rootlets of legumes and other orders of plants, are able to recover and again make available this loss. . . . .

> The fact that a few million years may supervene before the particle that is carried off to-day as waste may return to organic life, shows the patience rather than the wastefulness of nature.

> As a result of this general review of the migrations of plant food, the reassuring conclusion is reached that there is no danger whatever of the ultimate consumption or waste of the materials on which plants live. Circumscribed localities, through carelessness or ignorance, where once luxuriant crops grew, may become sterile, but the great source of supply is not exhausted. In fact, as the rocks decay and nitrifying organisms increase, the total store of plant food at the disposal of vegetation may continue to grow. When we join with this the fact that the skill of man in growing crops is rapidly increasing, we find no danger ahead in respect of the quantity of human food which may be produced.

It is evident that plants, like animals, cannot thrive without proper care, and food is just as important in the development of high grade plants and abundant crops as it is in the production of high grade cattle and sheep. The soil was regarded for many centuries as dead matter, containing certain stores of plant food, but one of the first things observed in these investigations which were made was that soil is a living body and as such entitled to have a hygiene and physiology of its own. The study of the soil thus becomes not alone a problem in mineral chemistry but a biological problem of the highest importance and significance. In the Bureau of Chemistry were made the first systematic studies in this country of the organisms of the soil which produce nitric acid, one of the most important elements of plant food.

Elaborate experiments were conducted in a series of pot cultures to establish the conditions of maximum activity of nitrification and the relative nitrifying power of different soils.

samples of which were taken under such conditions as to insure normal bacterial activities. These led to the important observation that the chemical composition of plants when mature was influenced in the most remarkable degree by the environment to which they were subjected, and that the influence of the soil in determining the quality of the plants was far less significant than had usually been supposed.

An extensive investigation was undertaken on the influence of environment upon the composition of wheat and other cereals, upon the production of the maximum amount of sugar in the sugar beet, and upon the distribution and qualities of the best varieties of green sweet corn, cantaloupes and other crops. The plan of investigation followed in these studies is, I believe, original and has now been very closely adopted in Australia and some other countries. Briefly, the plan of study was to distribute the same seed in widely different localities and have these seeds planted and cultivated in as nearly as possible the same manner. After being properly harvested and cared for, the crops were chemically examined and compared with crops grown in the mother State. It is evident that in this way the differences in composition were not due to any inherent properties, that is, due to heredity, but to the forces of the environment under which the crops were produced. Several elaborate monographs have been published on this subject and among these the one of the greatest economic significance is the result of the studies, covering more than fifteen years, on the effect of the environment upon the production of the maximum quantity of sugar in the sugar beet. As a result of these prolonged studies a biological map of the sugar beet area was constructed, indicating by a shaded band stretched from the Atlantic to the Pacific those areas in the United States where the richest sugar beets would be likely to grow. The practical benefit of this study is shown in the fact that many intending investors who were about to place their capital in beet sugar enterprises in unpropitious localities were deterred from doing so by the results of these studies, and thus hundreds of thousands of dollars were saved which otherwise would have been squandered. The most remarkable practical demonstration, however, of the value of such studies from an economic point of view is in the fact that practically every beet sugar factory which has been

successful and which is now operating is located in the shaded
belt marked out now almost fifteen years ago. The studies
of all the factors in the production of a sugar beet of maximum
sweetness has led to the conclusion, based upon indubitable data,
that the dominant factor is a long day and a moderate tem-
perature, not varying very much from an average of 70° F.
for the three growing months of June, July and August. It
is evident, therefore, that a high northern latitude, combined
with a proper distribution of water by irrigation or otherwise,
is the only place where a sugar beet can be grown at the present
time which can compete with European grown sugar.

These are only some of the more important of the many
biological investigations which have been conducted in connec-
tion with the growth of crops and the increase of the food supply
of the country. The activities of the Bureau of Chemistry,
however, have not been confined to plant life. I am of the
opinion that the highest service of science is to man himself,
and that the welfare of the plant and of the animal, from an
ethical, moral and economic point of view, may have their
highest significance in their relation to the welfare of man. To
this end a great deal of the energy which has been expended in
the investigations of the Bureau of Chemistry has been directed
to problems involving human rights, the health of the people
and the honesty of trade.

I cannot undertake in these few moments accorded to me
to go into further detail respecting the agricultural and biological
investigations in which I have been interested and concerned.
I only wish to say finally that to me the most important of
the factors to be considered in this matter is the moral one—the
duty which is pointed out clearly by these investigations to
the farmer, the manufacturer and the dealer to refrain from
deception and debasement in the growth, manufacture and dis-
tribution of food products. I think it is evident to all that a
distinct revival of commercial honesty may be seen everywhere
as a result of these studies, not only in the trade in foods, but
in all trades. Congress has been led to supplement the food
law by enacting a similar law relating to insecticides and fun-
gicides. There is now pending before Congress a bill which
regulates the manufacture and sale of adulterated and mis-

branded paints. This bill has passed the House of Representatives. Bills have also been introduced before Congress relating to commerce in general and requiring that the manufacturer and dealer shall not misrepresent or debase the article which he has for sale.

Under the old principle of the common law the purchaser himself was held responsible for investigating the character of the goods he bought and this led to the maxim of the common law of *caveat emptor*. The statute of law, however, recognizes the helplessness of the purchaser in most cases to make such investigations and so under this law the legend has become *caveat vendor*. Especially is this true in respect of those who by reason of a tender age are incapable of looking out for themselves. In the case of infants' foods the duty of the State and municipality is plain. The only artificial food an infant deprived of its natural food should have is pure, fresh milk modified to be as much like mothers' milk as possible. Experience has shown that the death rate of artificially-fed infants can be materially reduced by a pure milk diet. What greater service may a municipality render its citizens than to save the lives of the children? It seems to me that the only immediate solution of the problem is the city-controlled milk supply for sick and motherless children. The city should own its own herd of healthy cows, kept in the best sanitary manner. The milk should be handled by the latest methods of transportation and delivered promptly to the consumer. It should be made an offense of the law to feed a demothered infant under one year of age any food save the pure modified milk. A charge equal to the price of ordinary milk should be made for the municipal milk which should be reserved solely for infants' use.

It seems to me that the most important lesson which is taught by the brief recital which I have given is the relation of scientific development to ethics and honesty. It is not claimed that all scientific men are honest or ethical. The percentage of bad men in scientific circles is probably as great as in any other, but the whole tendency of science is towards the glorification of the truth, and the truly scientific man stands with uncovered head in the presence of every great problem, devoutly praying that his investigations may be devoid of preju-

dice and free from error. That science fails of its purpose which does not have in view the welfare and happiness of man

As is the case with every other means of good so we must expect to see science sometimes prostituted to base ends. There is a Dr. Jekyll chemistry and a Mr. Hyde chemistry. Every protagonist of the unholy will be able to find somewhere a scientific defender. The cause of the corporation against the rights of the individual may be able to find a defender among the men who are supposed most of all to hold the truth in reverent affection. In the courts of justice the chemist and the bacteriologist will endeavor to safeguard their clients from the penalties of law breaking. But the great and overwhelming majority will stand for the right and fight the battles of righteousness. And in most cases where the scientific man appears to be on the wrong side he is more than likely to be perfectly honest in his views. I want to live to see a new emancipation day. That is indeed a glorious day now celebrated that marks the end of African slavery. But the white man is also entitled to his freedom. The thralldom of the dollar must be broken, mercenary interests must loose their hold on humanity. Righteousness and honesty must prevail. Then, and then only, will the new emancipation day come—the celebration of the end of the reign of Greed and Graft.

Duralumin, a New Light Alloy. ROBT. GRIMSHAW. (*The Metal Industry,* viii, 9.)—Duralumin is the name given to a series of light and tough alloys, invented by Herr A. Wilm, of Sehlachtensee, near Berlin. One of this series contains 90 to 95 per cent. of aluminum, and has nearly the same properties as good Bessemer steel, except that its specific gravity is only about 2.8. This metal has great value not only for aviators but also for manufacturers of cartridges. For this manufacture a hardness of 160 at the base is required to prevent expansion with the blow of firing. The hardest alloy of this series reaches 125 in its natural state, which may be increased by cold hammering to 174, taken by the Brinell test. By using one of the hardest of the alloys and treating the metal hot, the hardness is reduced so as to lighten the operations to which it is submitted. For airships the stretch under extension must not be over 8 per cent. Tests show that the new alloy breaks at 62 Kg. per square mm. or 88,000 lbs. per square inch.

THE VALUE OF CERTAIN PAINT OILS.

BY

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THE recent activity of the paint chemist in searching for oils to partly replace linseed oil, has come not only as a result of the present scarcity of the latter commodity, but through a desire to develop a vehicle that will be for certain technical paints even more satisfactory, if possible, than linseed oil.

It is not the writer's intention, however, to encourage the use of so-called substitutes for linseed oil. The market is flooded with them at the present time, and great danger will lurk in their use until their composition is understood or their value determined in a practical way.

The real object of this paper is to present a summary of the results obtained by the writer from a series of experiments on paint vehicles, which may serve to guide other investigators along similar lines of research. The tests outlined herein, although of interest in pointing out the possibilities of the use of many oils `other than linseed, are, nevertheless, tentative in nature and subject to confirmation through practical field exposure tests before they are to be accepted commercially.

It is well known that a most desirable feature of paint oils is their ability to set up in a short period to a hard surface that will not take dust, that will stand abrasion and offer resistance to moisture and gases. This drying property is dependent upon the chemical nature of the oil. If it is an unsaturated compound, like linseed oil, rapid absorption of oxygen will cause the film to dry rapidly and become hard. If the oil be of a fully satisfied nature, like mineral oil, for example, oxygen cannot be taken up to any great extent and drying will not take place. The various animal and vegetable oils differ in their power of oxygen absorption to a lesser or greater extent. This difference is referred to by the chemist in terms of the iodine value. The iodine value of linseed oil is approximately 190, meaning that one gramme of the oil will take up 190 centigrammes of iodine.

Soya bean oil which has presented itself as a claimant for distinction in the list of paint oils, is now being imported into this country in large quantities. It is obtained from the seeds

TABLE I.

CHEMICAL CHARACTERISTICS OF SOYA BEAN OIL.

Sample No.	Specific gravity	Acid No.	Saponification No.	Iodine No.	Per cent. of foots
1	0.9233	1.87	188.4	127.8	3.81
2	0.9240	1.92	188.3	127.2	. . . .
3	0.9231	1.90	187.8	131.7	. . . .
4	0.9233	1.91	188.4	129.8	. . . .
5	. . . . . .	. . . .	. . . . .	130.0	. . . .
6	. . . . . .	. . . .	. . . . .	132.6	. . . .
7	. . . . . .	. . . .	. . . . .	136.0	. . . .
Average..	0.9234	1.90	188.2	130.7	. . . .

of Soya Hispida, a plant indiginous to Manchuria, but raised extensively in our own Southern States as a cattle food.

The writer has examined a number of representative samples of the oil that have come into this country, and the results obtained can be seen in Table I.

TABLE II.

IODINE VALUES OF LINSEED OIL AND MIXED OILS.

Sample No.	Straight linseed	Soya, 25 per cent.; Linseed, 75 per cent.	Soya, 50 per cent.; Linseed, 50 per cent.	Soya, 75 per cent.; Linseed, 25 per cent.
1	190.3	175.2	160.7	140.4
2	189.5	175.9	161.7	140.8
3	188.0	175.4	160.3	139.0
Average	189.3	175.5	160.9	140.4

It is evident that the iodine value of soya bean oil is the only chemical characteristic that markedly differentiates it from linseed oil. Therefore, in the detection of soya bean oil and its estimation, the iodine values of several samples of mixed oils are given, as being of interest in this connection (Table II).

A series of tests were conducted to determine what drier was the most efficient to use with soya bean oil, and the results of these tests indicated that the percentage of lead or manganese, or of lead and manganese, which gave the maximum efficiency in the drying of linseed oil, gave also to soya bean oil the best results. The methods used in carrying out the tests were the same as on linseed oil, referred to later in this paper.

A definite quantity of oil was placed in weighed friction-top can covers, which were re-weighed after receiving the oil, to determine the amount used for the test in each case. The tin covers containing the oil were then placed in a large box under definite temperature control and humidity, for a certain period. Weighings were made at different periods, and the increases in weight, due to absorption of oxygen, was calculated to percentages.

Table III gives the results obtained. The time of drying was somewhat longer than with linseed oil.

Several test panels were painted with zinc and lead, alone and in combination, using linseed oil, soya bean oil, and mixtures of the two. No driers were used in these paints, as the object of the tests were to determine the drying action of the oils, without driers. The drying of the linseed oil paints was very good in less than two days, while the straight soya bean oil required nearly four days to set up, and was then tacky for a long period. Laboratory tests of a preliminary nature made with mixtures of the two oils, ground with pigments, so far have indicated that a moderate percentage of soya bean oil is not detrimental when used with linseed oil.

The writer has found that a few drops of soya bean oil placed in a porcelain dish will give with a drop of strong sulphuric acid, faint fluorescent yellow and green colors, forming a pattern distinct from the dark-brown begonia-shaped leaf formed by sulphuric acid with pure linseed oil. Many other qualitative tests have been tried to detect the presence of soya oil in admixture with linseed oil. Soya oil seems, however, not to possess the chromogenetic properties of oils, such as cottonseed oil.

Tung oil, or Chinese wood oil, as it is often termed, has been considered heretofore as an oil most valuable in the manufacture of varnishes, but seldom if ever to be used as a paint

oil. As a matter of fact, however, in manufacturing, certain technical paints for the protection of concrete and steel, the water-proofing of structures, and for other purposes, the manufacturer may find this oil, or its products, most useful, and to be prized very highly. Toch, as well as Lewkovitch, have shown

TABLE III.
Soya Bean Oil and Lead Dryer.

Per cent. PbO.		0.05	0.10	0.30	0.50	0.70	1.00	1.30	1.60
Per ct. gain	1 day..	....	0.07	0.63	1.34	1.05	1.53	0.93	1.35
	3 days.	....	0.07	3.52	4.31	2.75	4.86	4.82	4.12
	5 days.	....	0.09	5.04	6.06	6.09	6.75	6.66	5.52
	12 days.	....	....	6.88	7.54	7.43	7.76	7.32	6.47
	15 days.	....	....	8.84	8.93	8.59	8.81	8.44	7.46
	20 days.	0.05	0.20	9.02	9.08	8.90	9.03	8.65	7.83

Soya Bean Oil and Manganese Dryer.

Per cent. MnO₂		0.01	0.05	0.15	0.26	0.30
Per ct. gain	1 day.. ...	....	....	0.02	0.02	0.01
	10 days....	....	5.06	6.48	6.10	5.97
	20 days....	0.05	9.07	8.80	6.78	6.51

Soya Bean Oil, Manganese and Lead Dryer.

Per cent. PbO......................		0.20	0.30	0.50
MnO₂............		0.05	0.15	0.25
Per ct. gain........	1 day.....	3.04	3.77	3.74
	8 days....	5.96	6.43	6.47
	12 days....	6.33	6.78	6.67

that metallic tungates are most excellent driers, and the former paint technologist,[1] has indicated their value for certain special purposes. The high iodine number of tung oil makes it a most rapid drier, even faster than linseed oil, but the soft and opaque film it leaves upon oxidation, makes essential its treat-

[1] Toch: "The Newer Paint Materials," The Decorator, London, Nov. 22, 1910, p. 174.

ment by special processes when it is used either for varnishes or for paints, except in special cases.

The writer has prepared the tungate of lead by precipitating saponified tung oil with lead acetate. This tungate after it has been freed from water, may be fused with a small percentage of colophony and borate to produce a rapid drier that gives a perfectly clear film. Experiments with this drier are referred to later.

Menhaden oil, although of marine-animal origin, has a high iodine value, as the following recent tests will show:

```
Sample number 1 ............................... Iodine,  149
Sample number 2 ............................... Iodine,  162
Sample number 3 ............................... Iodine,  164
Sample number 4 ............................... Iodine,  158
Sample number 5 ............................... Iodine,  161
```

The oil obtained from fresh fish is extremely light in color, but the odor is objectionable, when the oil is heated. This oil is a fairly rapid drying oil, and its composition would indicate that it might possess considerable merit. Toch claims that it is of great value for smokestack paints, and for zinc paints exposed at the seashore. Its content of stearine might account for certain waterproofing properties claimed by producers and would suggest its use in paints for the protection of iron and steel.

Some of the other oils used in these experiments will be considered briefly. Cottonseed oil and corn oil are both light in color, and although greatly inferior to even soya bean oil in their drying action, should merit further investigation.

Rosin oil, the product of the dry distillation of rosin, is dark and viscous. It has a low iodine value, and a high acid number that unfits it for general use as a painting oil.

Sunflower oil is high in iodine number, light in color, but very scarce. There seems to be no reason, however, why the seed should not be grown in larger quantities in this country and the oil produced as a painting oil.

Perilla oil is very high in iodine number, even higher than linseed oil, but it also is very scarce. It is obtained from the Perilla nuts, grown in Manchuria and the East Indies. Its iodine number is 206, but Lewkovitz claims that its drying action is accompanied by a peculiar " dropping " of film. This con-

dition might be overcome by special treatment. The writer has not made any experiments on this oil.

Waste oil, or the mixture of fatty acids, and glycerides obtained from the garbage in large cities, is being produced and used in great quantities as soap oils, but the investigations of the writer on several samples, has shown this product to be of small value as a paint oil. Its use in combination with linseed oil to produce a soft, elastic, water repellant film for paints to protect iron and steel submerged in sea water should be studied.

There are several blown and oxidized linseed and other oils upon the market that are so thick that 50 per cent. of benzine or other diluent is required to reduce them to painting con-

TABLE IV.

CONSTANTS OF VARIOUS OILS.

	Specific gravity	Iodine number	Acid number	Saponification number
Linseed oil.............	0.934	188	3	191
China wood oil..........	0.942	172	5	190
Soya bean oil..........	0.922	134	2	188
Menhaden oil...........	0.935	160	5	189
Sunflower oil...........	0.929	128	4	188
Cottonseed oil..........	0.923	110.	4	...
Corn oil...............	0.924	117	8	190
Rosin oil..............	0.989	28	.	...
Waste oil..............	.....	60	34	...

sistency. There are also several debloomed mineral oils which resemble linseed oil only in viscosity and their value should be looked into with great care before they are used.

There are on the market many so-called Japan oils. The base of many of these oils is melted rosin, thinned with some linseed oil and large quantities of benzine. Their use is not to be recommended until practical tests of their value have been made.

A table (Table IV) of constants of various oils was made from recent experiments, the oils being subsequently used for the tests referred to in Table V.

The following drying tests (Table V) were made by painting thin films of oil on glass plates, exposing to the atmosphere, and carefully observing the time of the drying. These tests do not indicate the wearing value of the oils tested, but are

simply criterions of their relative drying values. Although
sample No. 2, which is untreated tung oil, dried with Drier
X, more rapidly than untreated linseed oil with Drier X, it

TABLE V.
DRYING TEST OF OILS.

Sample		Hours
No. 1	*Pine oil with 10 per cent. Drier X....................	$2\frac{1}{2}$
No. 2	Tung oil with 10 per cent. Drier X....................	$2\frac{3}{4}$
No. 3	Linseed oil with 10 per cent. Drier X.................	3
No. 4	Linseed oil.....25 per cent. Soya bean oil...25 per cent. Menhaden oil...25 per cent. Tung oil........15 per cent. Lead tungate...10 per cent. }	3
No. 5	Linseed oil......75 per cent. Chinese wood oil 25 per cent. } with 10 per cent. Drier X	3
No. 6	Linseed oil..75 per cent. *Pine oil....25 per cent. } with 10 per cent. Drier X...	3
No. 7	Linseed oil.....50 per cent. Menhaden oil...25 per cent. Soya bean oil...15 per cent. Lead tungage...10 per cent. }	$3\frac{1}{4}$
No. 8	Menhaden oil with 10 per cent. Drier X...............	$3\frac{1}{2}$
No. 9	Soya bean oil with 10 per cent. Drier X...............	$3\frac{1}{2}$
No. 10	Linseed oil.....80 per cent. Waste oil.......10 per cent. Lead tungage...10 per cent. } with 10 per cent. Drier X	$3\frac{1}{2}$
No. 11	Linseed oil.....75 per cent. Soya bean oil...25 per cent. } with 10 per cent. Drier X	4
No. 12	Linseed oil.....75 per cent. Corn oil........25 per cent. } with 10 per cent. Drier X	$5\frac{1}{2}$
No. 13	Linseed oil.....75 per cent. Cottonseed oil...25 per cent. } with 10 per cent. Drier X	$6\frac{1}{2}$
No. 14	Linseed oil.....75 per cent. Rosin oil.......25 per cent. } with 10 per cent. Drier X	10
No. 15	Corn oil with 10 per cent. Drier X....................	8
No. 16	Cottonseed oil with 10 per cent. Drier X.............	9
No. 17	Rosin oil with 10 per cent. Drier X................. {	Not dry in 2 day

* Pine oil referred to is not rosin oil but the high-boiling-point distillate of wood turpentine.

is the writer's opinion that the linseed oil would be the more
serviceable. The pine oil referred to in these tests is not the
pine oil of commerce, but a product of the refining of wood

turpentine. 'Drier X' referred to was a strong lead and manganese linoleate drier.

The only practical field tests made by the writer thus far on the value of oils, other than linseed oil, are those at Nashville, Tenn., where a fence has been erected, consisting of 42 tests of white paints. In these tests pure linseed oil was used, except in formulas 31 to 42.

On these tests there have been placed one formula which has given satisfaction on the various other test fences erected, and this formula has been made up with combinations of linseed oil and other oils. One of the oils tested is called pine oil, a high-boiling-point product obtained from the manufacture of wood turpentine from sawdust. This has a boiling point of over 210° C. as against 150°, the boiling point of ordinary gum spirits. It is almost water white and has the same penetrating qualities as the pure gum spirits, and is almost free from that objectionable odor characteristic of so many low-boiling-point products. When mixed with 50 per cent. linseed oil, this product forms a paint oil of extremely light color, and most excellent properties, producing a semi-flat paint of great whiteness. If exposure tests prove this oil as worthy as the tests thus far show, it would appear to be of great importance to the Southern manufacturers to produce this material in quantity, by fractional distillation of the crude spirits. Its iodine number is high and its oxygen carrying properties are good. Its evaporation leaves a durable film.

The tests referred to on the Southern Test Fence are as follows:

Composition of Formulas.

No. 31
- Corroded white lead..45 per cent.
- Zinc oxide ....45 per cent.
- Asbestine .... 5 per cent.
- Calcium carbonate .... 5 per cent.

Ground in pure linseed oil.

100 per cent.

No. 38—Same as No. 31 but ground in 50 per cent. raw linseed oil, 50 per cent. soya bean oil.

No. 39—Same as No. 31 but ground in 50 per cent. raw linseed oil, 50 per cent. corn oil.

No. 40—Same as No. 31 but ground in 50 per cent. raw linseed oil, 50 per cent. cotton seed oil.

No. 41—Same as No. 31 but ground in 50 per cent. raw linseed
        oil, 50 per cent. rosin oil.
No. 42—Same as No. 31 but ground in 50 per cent. raw linseed
        oil, 50 per cent. pine oil.

Driers.—The problem of drying of oils and their behavior
with various siccatives in varying quantity is an interesting one,
and, obviously, of considerable importance from a practical stand-
point. Unfortunately there is a decided scarcity of reliable
literature dealing with the subject for the guidance of those
concerned in the manufacture or application of siccative products.
Furthermore, when the problem is investigated, it is not difficult
to see why this is so.

At a glance, it is evident that a decided obstacle in ex-
perimentation on the drying properties of oils, is the difficulty
in obtaining identical conditions for comparative purposes. In-
asmuch as a multitude of factors, such as uniformity and homo-
geneity of the driers and the oils themselves, intensity and
source of light, temperature, uniformity of application, and
many others, play a decisive part in the siccative tendencies of
oils, the resources and ingenuity of the chemist engaged in the
research are severely taxed.

It is a well-known fact that linseed oil, when applied to a
clean surface, such as a glass plate, will undergo oxidation and
take up oxygen to the extent of about 16 per cent., forming a
hard, elastic, non-sticky product which has been called linoxyn.
This material, unlike the oil from which it has been formed, is
insoluble in most solvents. Other oils, such as cottonseed, hemp,
rape, olive, etc., are more fully satisfied in nature and have
not the power to absorb the amount of oxygen taken up by
linseed oil. It is said that perilla oil, however, will absorb
as high as 20 per cent. of oxygen.

In carrying out the following tests, on the drying of oils,
a quantity of pure linseed oil of the following analysis was
secured :

Specific gravity at 15° C.	0.934
Acid number	5
Saponification number	191½
Iodine number	188

This oil was distributed into a number of 8 oz. oil sample
bottles, and to a series of these bottles was added varying quan-

tities of a very concentrated drier made by boiling oil to 400°
C. in an open kettle, with the subsequent addition of lead oxide.
The amount of drier added to each bottle varied according
to the percentage desired; being calculated on the lead con-
tent of the drier, which was very accurately determined by
analysis.

There was secured in this manner a series of oils contain-
ing varying amounts of lead oxide, and from this lot was
selected a certain number of samples which would be repre-
sentative and typical of paint vehicles now found in the market.

Another series of tests were made by combining with a
large number of samples of pure linseed oil as used above,
various percentages of a manganese drier made by boiling oil
at 400 degrees and incorporating therewith manganese dioxide.

Still another series of tests were made upon a number of
oils into which were incorporated various small quantities of
lead oxide and manganese oxide together, using the standard
driers made in the above manner, all of which were carefully
analyzed to determine their contents.

In view of the errors in manipulation that could occur
where so many tests were made, it was not deemed advisable,
in carrying out the tests, to use glass plates, on which only
a minute quantity of oil could be maintained. A much better
solution of the difficulty presented itself in using a series of
small, round, crimped-edge tin plates about three inches in
diameter, such as are used for lids of friction-top cans.

With paints it is impossible to secure films as thin as those
presented by layers of oil on glass, nor would it be desirable
to secure films of this same relative thickness. For this reason,
an endeavor was made to conduct the following tests with films
of the same relative thickness as that possessed by the average
coating of paint. The drying of the films did not take place
in the same short period, nor in the same ratio as with the
thin layer that is secured by flowing oil upon glass. The
results, however, are more practical, and of greater value to
the manufacturer.

The cans were carefully numbered in consecutive order,
corresponding to the numbers on the various samples of oil.
A very small quantity of oil was placed in each of the can
covers, which were previously weighed, and allowed to dis-

tribute itself over the bottom surface thereof. Re-weighing of the covers gave the amount of oil which was taken for each test. The test samples in the covers were all placed in a large box with glass sides, having a series of perforated shelves. In the side of this box as an opening through which a tube was passed, carrying a continual current of air washed and dried in sulphuric acid. Oxidation of the oil films commenced at once, and the amount of oxygen absorbed was determined at suitable periods, by weighing, the increase in weight giving this factor. This test was kept up for a period of twenty days.

A test was also made in the same manner with a current of damp air passing into the box, to observe the relative oxidation under such conditions.

The experiments consumed considerable time and effort. A chart of the results obtained have been made (Table VI), to show the effect of the various driers.

The following outline will present to the mind of the reader the most salient points which have been gleaned from these experiments, and which should give the manufacturer definite knowledge as to the best percentage of oxides to use either in boiled oil, paints or varnishes.

· In the case of lead oxide, an increase in the percentage of lead oxide in the oil causes a relative increase in the oxygen absorption, but when a very large percentage of lead has been added, the film of oil dries to a leathery skin.

In the case of manganese oxide, the increase in oxygen absorption on the first day is much more pronounced than is the case with lead oxides. Furthermore, the oxidation of manganese oils seems to be relative to the increase in manganese up to a certain period, when the reverse of this law seems to take place, and beyond a certain definite percentage of manganese, added percentages seem to be of no value. It was furthermore observed that the films dry to a more brittle and harder skin than is the case with lead oxide. The oxygen absorption with oils high in manganese has been noticed to be excessive, and the film of oil becomes surface-coated, drying beneath in a very slow manner, a condition that often leads to checking. The critical percentage where the amount of manganese appears to be most propitious and renders the greatest efficiency seems to be 0.02 per cent. This critical percentage,

TABLE VI.

LINSEED OIL AND MnO₂ (Manganese) DRYER—TEST No. 1.

Per cent. MnO_2	0.02	0.05	0.15	0.25	0.35	0.45	0.55	0.70	1.00
1 day	0.08	0.11	0.16	....	3.21	3.46	3.27	3.01	2.76
2 days	0.16	5.88	4.48	....	3.63	4.01	3.70	3.51	3.18
3 days	0.21	6.79	4.61	....	3.83	4.31	....	3.91	....
4 days	....	....	4.64	....	....	....	....	....	....
5 days	3.01	6.84	....	....	4.13	4.68	4.19	3.91	3.99
6 days	8.00	....	4.88	....	4.37	....	4.51	4.32	4.13
7 days	8.58	6.92	4.90	....	4.48	....	4.61	4.52	4.23
8 days	9.06	....	5.03	....	4.55	5.23	4.77	4.62	4.44
9 days	....	....	5.12	....	4.63	5.40	4.94	4.79	4.51
10 days	9.07	6.89	5.18	....	4.81	5.47	....	4.98	4.73
11 days	9.15	7.03	....	....	....	....	....	....	....
12 days	....	....	....	....	4.98	....	....	....	....
13 days	9.22	7.17	....	....	5.25	6.00	5.45	5.33	5.22
14 days	9.25	7.18	5.55	....	....	....	5.60	5.42	5.33
20 days	....	7.21	5.81	....	5.84	6.70	5.94	5.84	5.77

Per cent. gain..........

Above percentages of drier reckoned to metallic content.

TABLE VII.

LINSEED OIL AND MnO₂ (MANGANESE) DRYER—TEST No. 2 (CHECK).

Per cent. MnO₂	0.00	0.02	0.05	0.10	0.15	0.25	0.35	0.45	0.55	0.70	1.00
Per cent. gain											
1 day				3.12	4.42	3.86	3.72	3.19	2.98	3.27	2.56
2 days			0.28	6.15	4.73		3.87	3.51	3.28	3.70	2.96
3 days			3.83	6.29		4.12			3.39	3.71	3.15
4 days			6.64	6.32	4.75		3.94	3.61	3.58	4.05	3.43
5 days			8.61		4.84	4.21	4.08	3.73	3.65	4.21	3.56
6 days			9.07	6.35	4.87	4.23	4.18	3.81	3.78	4.35	3.73
7 days			9.25	6.39	5.00		4.44	3.91	3.85	4.54	3.87
9 days					5.16	4.41	4.59	4.11	4.21	4.63	4.26
11 days				6.43		4.63		4.36	4.31	5.07	4.46
16 days					5.30	4.91	4.83	4.72	4.71	5.40	4.87

TABLE VIII.

LINSEED OIL AND PbO (LEAD) DRYER.

Per cent PbO.	0.00	0.05	0.10	0.30	0.50	0.70	1.00	1.30	1.60
Per cent. gain									
1 day	0.042	0.049	0.092	0.058	0.066	0.062	0.062	0.079	0.039
2 days	0.098	0.104	0.153	0.116	0.158	0.185	0.194	0.194	4.79
3 days	0.128	0.159	0.170	0.137	0.279	4.07	7.11	4.83	5.35
4 days	0.164	0.214	0.206	0.178	0.340	7.60	7.39	8.60	8.53
5 days	0.176	0.231	0.306	0.243	0.472	9.36	7.47	9.55	8.78
6 days	0.188	0.251		0.253	0.080	10.06	7.64	9.87	9.00
7 days	0.206	0.251	0.306	0.280	1.080	10.38	7.70	10.01	9.05
8 days	0.206	0.291		0.331	7.36	10.41	7.73	10.14	9.07
9 days	0.212	0.253			4.80			10.22	9.29
13 days	0.226	0.428	0.510	0.674	11.01	10.67	7.91	10.23	9.30
15 days	0.327	0.455	0.650	2.41	11.05		7.92	10.48	9.29
20 days	0.466	1.08	1.78	8.76	11.25	10.67	7.98	10.50	9.36
	0.521							10.52	

TABLE IX.

LINSEED OIL AND PbO (LEAD AND MnO₂) (MANGANESE)—COMBINATION DRYER.

Per cent. PbO	0.1	0.3	0.5	0.7	0.9	1.1	1.4
Per cent. MnO₂	.005	.015	0.025	0.35	0.45	0.55	0.7
1 day......	0.026	0.061	0.055	0.022	0.16	0.11	3.06
2 days.....	0.094	0.087	0.143	0.16	5.21	6.28	3.37
3 days.....	0.118	....	0.17	4.23	7.63	8.31	3.74
4 days.....	....	0.11	0.23	7.36	8.87	9.20	4.02
5 days.....	0.120	0.12	0.29	9.04	9.13	9.37	4.17
6 days.....	0.17	0.13	1.44	9.88	9.26	9.51	4.34
7 days.....	0.21	0.18	4.65	10.11	9.28	....	4.45
11 days.....	0.30	0.26	10.03	10.35	9.61	9.85	5.11
12 days.....	....	....	....	10.45	9.66	....	....
13 days.....	0.35	0.54	10.37	10.51	9.67	10.03	5.33
18 days.....	0.49	3.43	10.38	10.62	9.68	....	5.73

as it may be termed, should not be exceeded, and any added amount of manganese has the effect of making the film much more brittle and causes the so-called "burning up" of the paint. The loading of paint with drier and the bad result therefrom, may be explained to some extent from the above results.

In the same way with lead driers, excessive amounts of lead oxide seems to have no beneficial effect on the drying of an oil, and when the percentage which seems to be the most beneficial, namely 0.5 per cent. lead oxide, is exceeded, the film is apt to become brittle.

Oils containing lead oxide driers are less influenced in their drying tendencies by conditions of moisture in the atmosphere than oils containing manganese, but frequently, however, the former dry much better in a dry atmosphere. As a general rule, varnishes rich in manganese dry more quickly in a dry atmosphere, while those containing small quantities dry more quickly in a damp atmosphere.

It was furthermore noticed in these tests that sulphuric acid, placed in dishes on the bottom of the large box in which the samples of oil were drying, were discolored and turned brown after several days, showing that the acid had taken up some material of a volatile nature that was a product of the oxidation.

Another curious feature of these tests was the development of a peculiar aromatic odor which was given off by the oils upon their drying in dry air. When the oils were dried in moist air, a rank odor resembling propionic acid was observed, and this led the observer to believe that a reaction was effected by the absorbed oxygen, that caused the glycerin combined with the linoleic acid as linolein to split up into evil-smelling compounds. It has been suggested that the oxygen first attacks the glycerin, transforming it into carbonic acid, water and other volatile compounds, which are eliminated before the oil is dried to linoxyn. Toch,[2] however, has shown that the drying of linseed oil gives off only very small percentages of carbon dioxide. Mulder has observed that in the process of linseed oil being oxidized, glycerin is set free, which becomes oxidized to formic, acetic and other acids, while the acid radicals are

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[2] Toch: The Chem. and Tech. of Mixed Paints, p. 89. D. Van Nostrand, N. Y.

set free and are converted by oxygen into the anhydrides from which they pass by further oxidation into linoxyn.

The theory of auto-oxidation of linseed oil has been very ably treated by Blackler, whose experiments indicated that during the drying process the slow absorption of oxygen was, at a critical period, followed by a rapid absorption which he attributes to the presence of peroxides which accelerate oxidation. The materials produced by this peroxide formation may act as catalyzers and accelerate the formation of more peroxide. Lead and manganese oxides may also be oxidized to peroxides by the action of oxygen and in this event might act as very active caralyzing agents or carriers of oxygen. Blacker's statement that the presence of driers do not increase, but have a tendency to decrease the initial velocity of oxygen absorption, has been confirmed by these experiments, but it has been noticed throughout the tests that the driers have an accelerative action at a later period.

Some most interesting results were secured by dipping extremely fine copper gauze into linseed oil, and then suspending the gauze in the air. The adhesion of the oil to the copper caused the formation of films between the network, and remarkable drying action was observed. The copper or any superficial coating of copper oxide which may have been present on the metal, undoubtedly effected the result to some extent. It has been found that metallic lead is even more efficient than copper in this respect, but this may be due to the action of free acid in the linseed oil, forming lead linoleates, products that greatly accelerate drying. Another interesting experiment was made by taking pieces of gauze cloth and immersing in linseed oil. After the excess oil had been removed, by pressing, the cloth was again weighed to determine the amount of oil used for the experiment. The increase in oxygen absorption in this case was very rapid and the result obtained confirmed the results in the other experiments.

In order to secure a more evenly distributed state of the oil, tests were conducted by saturating pieces of stiff blotting papers and after exposure, weighing as usual.

The influence of light on the drying of oils is unquestionably a potent one. The practical painter knows that a certain varnish will dry quicker when exposed to the light than when in the dark.

Chevreul was one of the first pioneers in this field of research to observe the effects of colored lights on drying, and he claimed that oil exposed under white glass dried more rapidly than when exposed under red glass which eliminates all light of short wave lengths.

Genthe obtained interesting results in the drying of oil submitted to the effect of the mercury lamp. Oxidation without driers was effected probably through the formation of peroxides. In commenting on this subject, Blacker [3] gives a description of the use of the Uveol Lamp, which is similar to the mercury lamp, but has instead of a glass casing which cuts off the valuable rays, a fused quartz casing which allows their passage.

In the boiling of linseed oil, by certain processes the oil is heated to 250 degrees and manganese resinate is incorporated therein. It goes into solution quite rapidly. In other processes the oil is heated to 400 degrees or over, and manganese as an oxide is boiled into the oil. Although it is unsafe to say that a small percentage of rosin such as would be introduced by the use of resinate driers, is not harmful, yet it appears that this process should give a good oil, inasmuch as it has been found that no matter whether the manganese is added to the oil, as a resinate, borate or oxide, practically the same drying effect is noticed in every case where the percentage of manganese is the same. It is the opinion of some, however, that the resinate driers are not as well suited for durability as oxide driers. However, if a boiled oil is found to contain on analysis a small percentage of rosin (less than 0.5 per cent.) it should not be suspected of adulteration. Practical tests, however, should be made with such oil along with an oil made with an oxide drier, before pronouncing on their relative values. Inasmuch as the addition of certain driers to linseed oil lessens the durability of the film, it is more practical to use the smallest amount of drier that will serve the purpose desired, that is, set the oil up in a paint to a hard condition which will not take dust and which will stand abrasion.

The results of this investigation would indicate that when lead or manganese linoleates are used, the most efficient results may be obtained with 0.5 per cent. lead or with 0.05 per cent.

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[3] M. B. Blacker: "The Use and Abuse of Driers," P. and V. Society, London, Sept. 9, 1909.

manganese or with a combination of 0.5 per cent. lead and 0.02 per cent. manganese.

Until more definite results have been obtained with the *tungates,* which will probably prove of exceptional interest as driers, the above driers will probably be used to the greatest extent.

An Enormous Anchor. (*La Nature,* No. 1948, 130.)—In the Engineering and Machinery Exhibition opened in September at Olympia in London, there is to be seen an enormous ship's anchor which was forged by N. Hingley and Sons, of Dudley, for the "Olympic," the new giant White Star steamer. It weighs 15 tons, is nearly 20 ft. long, and its greatest thickness is 10 ft. The shank is 4 ft. 6 in. thick. It is furnished with a chain of three links each weighing 880 lbs. Twelve horses were required to drag it from Paddington to the exhibition. Another attraction is offered by Messrs. Siebe, Gorman & Co., in the demonstration of its new helmet which allows a man to plunge into water, or through flames or through noxious gases, with impunity. Men provided with this helmet walk at the bottom of a huge vat, filled with water, with glass sides, which allow their least motion to be seen clearly. Their only communication with the outside world is a telephone wire, through which they converse with the spectators.

Crystal Forms which are Stable only at High Pressures. A. SKRABAL. (*Zeit. Phys. Chem.,* lxxiii, 171.)—Tammann has stated that at present no rules can be formulated as to the separation of crystal forms of varying stability and that Ostwald's theory of successive reactions, when so applied, leads to conclusions at variance with the facts. The author believes that his statement of Ostwald's rule that the stability of thermal products is in inverse ratio to the speed of the reaction is in accord with the facts of crystallization. Hence the formation of diamonds by the crystallization of carbon from molten cast iron would be the result of rapid cooling, while graphite would result from slow cooling.

Boroid, a Substitute for Celluloid. ANON. (*Electrician,* lxv, 533.)—A new substance named boroid has been found in commerce recently, which is completely noninflammable. Its use as an insulator and especially as a substitute for celluloid in cinematograph films is to be recommended. On account of its noninflammability its superiority to celluloid for cinematograph films is beyond question.

THE STRETCHING OF A CONDUCTOR BY ITS CURRENT.

BY

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Text-books and treatises on physics teach about the mechanical forces which exist between neighboring conductors in which currents flow and between such conductors and a magnet, as these important forces are the basis of the ordinary electric motor and dynamo and explain other electrical motive devices. But they do not teach about any mechanical forces in the conductor itself produced by its own current, when the conductor is removed from all other circuits or magnets. It is not meant hereby that such internal forces were never thought of or that they never have been mentioned in the more obscure literature; it is believed to be a fact, however, that the usual treatises and text-books do not mention, describe or discuss them, and that therefore the average student has no knowledge of them, hence would not consider them in his subsequent practical work. In the opinion of the writer, however, the modern student ought to be prepared to deal with such new forces when he meets with them in new problems. In the more usual problems of engineering, such internal forces may no doubt be neglected; but when the currents become very large, as in some electric furnaces, or in short circuits, forces which ordinarily are negligibly small, may become quite formidable, particularly in liquids which will yield to even small forces, hence in molten masses in electric furnaces.

One such internal force was recently discovered by the writer and was found to be quite formidable, so much so that it placed a serious limit to the current which can be passed through a conductor under certain conditions; if there is one such formerly unknown force, why could there not be others also.

The purpose of the present article is to give certain reasons which tend to show that a force lengthwise to a conductor ought to be produced by the current flowing through it; and to describe some experiments, which are believed to be new, which show that such a force exists. It acts as an internal force which tends to

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stretch and lengthen the conductor, and therefore does not move it as a whole like an external force would; external movements can, however, be produced by it just as the internal forces in a stretched rubber band can produce external motions.

A noted physicist recently said to the writer that no force in the direction of the conductor was known, and that it would be wonderful if one were found to exist. While the former may be true, the writer does not see why its existence would be wonderful; the other internal force mentioned above was entirely unsuspected only a few years ago, yet now that we understand it, its existence does not appear wonderful. Concerning electromagnetic forces in general another noted physicist recently said, " The whole field is one of great mystery and is as yet only glimpsed at, so far is it from being comprehended."

The following eight observations or deductions led to the belief that such a stretching force exists.

a. By the internal forces producing the now well-known " pinch phenomenon " referred to above, the current tends to contract the cross section of the conductor; when the latter is solid, this force cannot manifest itself and was therefore not noticed before; but in a liquid, which readily responds to forces, it becomes very evident, contracting the conductor at its electrically weakest spot, and if strong enough it may even cause actual rupture. This has been described in detail [1]; the only feature of importance in the present discussion is that when a current passes through a conductor it produces radial forces which tend to force the outside of a conductor to the middle even to the extent of completely severing it. This force, like most other electromagnetic forces, is explained to act perpendicularly to the direction of the current; it has become a habit to explain new phenomena by means of such transverse forces because they are familiar to us.

It is a fact, however, that when a conductor contracts in cross section under this radial force, the material of the conductor also moves lengthwise to the conductor somewhere near the central axis, and with considerable force. This flow of the material is

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[1] A Practical Limitation of Resistance Furnaces; the " Pinch Phenomenon." Trans. Amer. Electrochem. Soc., 1907, vol. xi, p. 329. The Working Limit in Electrical Furnaces Due to the " Pinch Phenomenon." Trans. Amer. Electrochem. Soc., 1909, vol. xv, p. 255.

about as shown in Fig. 1, which represents a lengthwise vertical section of a liquid conductor carrying a current. One is therefore justified in saying that the conductor acts as though it were being stretched lengthwise, thereby piling up the material at the ends of the tank, which causes it to flow back again into the hollow or pinched part.

It is true that this phenomenon may be completely and perhaps more satisfactorily explained on the assumption of only transverse, radial forces, the horizontal flow being then due merely to the squeezing action of this radial force causing the liquid to flow lengthwise in the same way as it would in a rubber tube filled with water and squeezed by the hand. It is known, however, that most electrical phenomena can be explained correctly in two or more different ways; why then should not this one be capable of an explanation on the assumption of a longitudinal stretching
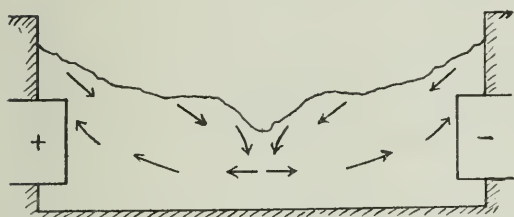
FIG. 1.   FIG. 2.
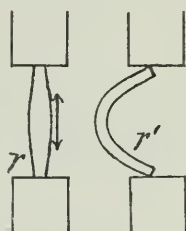
force instead of a transverse compressive one. Until the former can be disproved by an experiment or by a satisfactory argument, it cannot be said to be an incorrect or unallowable assumption.

b. The second observation which led to the belief of the existence of a stretching force is the electric arc. When horizontal it forms an arch (whence its name) as though the arc itself, which is a perfectly flexible conductor, were stretching itself, often to the extent of rupture. This is usually explained as being caused by heated air currents, which no doubt is true in part; but does it not also do so when the arc is between vertical electrodes; all the diagrammatic pictures of vertical arcs in the older books show it so. The flickering of an arc is often caused by the arc itself wandering about where it has more room to stretch out and it sometimes even crawls up the side of the electrode, as though it were trying to lengthen itself. In this respect an arc acts like a compressed rubber rod r, Fig. 2, which tends

to stretch itself, and if it can do so this stretching force tends to
make it take the position r'.

   c. The third deduction is illustrated in Fig. 3, which repre-
sents in perspective a bent current-carrying conductor flexible at
the corner. The encircling magnetism produced by the current
may be represented by the four small magnets as shown. The
nearer ones will repel each other more than the others, thus ex-
erting a force tending to straighten the conductor ; when straight,
the repelling force of these two magnets becomes equal to that
of the other two and the straightening action therefore ceases,
but the forces which did it *still exist,* hence tend to stretch the
straight wire.

   This is also shown in the well-known experiment of a circular
ring of mercury which becomes larger and larger by the action of
the current in it, it tends to expand ; a tendency to straighten itself
would cause such an expansion. Why should we say that this
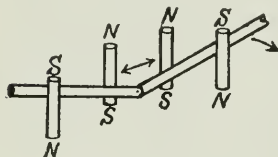
FIG. 3.   FIG. 4.   FIG. 5.
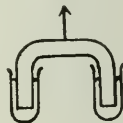
force ceases when the circle has become infinitely large and is
therefore a straight conductor, especially when we know that it
will then tear itself to pieces by the pinch effect, if the current is
great enough. In an induction furnace this expanding force is
said to become so great at times that one can see the bottom of
the circular crucible, the metal being forced radially up against
the inner side of the outer wall, as if by centrifugal force.

   d. A fourth observation is Ampere's well-known trough ex-
periment shown in Fig. 4, in which a bridge conductor B floating
on the two mercury troughs, is moved as shown as though the
conductors tried to become longer. This will be referred to again
below.

   e. A fifth deduction is that, as like magnetic lines of force
repel each other, and as every current-carrying conductor is en-
circled by like circular lines of force, these lines must repel each
other in the direction of the axis of the conductor, hence produce
a stretching force.

f. A sixth deduction is based on the result found by the writer nearly nineteen years ago,[2] that the quantity of magnetic flux produced by an ampere in every centimetre of length of conductor is a constant, assuming no iron, no neighboring conductors or magnetism and a filamental conductor. If, therefore, a conductor be stretched to say double its length (which is possible if it is a liquid, or by means of a sliding contact), the current remaining constant, there will be produced twice the flux. The magnetic flux will have been increased in direct proportion to the lengthening of the conductor.

All experiments with movable circuits and magnets seem to show that that motion will always tend to take place which will increase the magnetic energy of the combination; the mechanical forces will therefore be such as would bring about those motions. As lengthening a conductor increases the magnetic flux, it indicates that there exists a force tending to lengthen it.

Stretching a current-carrying conductor should therefore produce a counter e.m.f., as in a motor; the overcoming of this counter e.m.f. by the source of current represents some mechanical work set free, in this case the lengthening of the conductor. Conversely, compressing a current-carrying conductor should generate an e.m.f., hence be a conversion of mechanical into electrical energy, as in a dynamo.

g. A seventh observation is that shown in Fig. 5.   A U-shaped copper bar placed into two mercury-cup terminals will be forced up out of the cups with considerable force, when the current is strong enough.   This might be said to be a direct consequence of Ampere's trough experiment shown in Fig. 4.

h. The eighth deduction is from a recent statement by Dr. C. P. Steinmetz,[3] that " mechanical forces are exerted only where the inductance of the circuit changes with the mechanical motion which would be produced by these forces."   The lengthening of a conductor increases its inductance (see *f* above), hence if the converse of the above statement is true, the mechanical force of stretching the conductor should be exerted because the induction changes with the lengthening which would be produced by this stretching.   This deduction is similar to that in *f*.

[2] Ampere-Centimeter, a Measure of Electromagnetism. Jour. Franklin Inst., vol. cxxxiv, p. 69. Elec. World, May 28, 1892, p. 363.

[3] Proc. Am. Inst. Elec. Eng., Dec., 1910, p. 1916, bottom.

All these eight observations or deductions show that the exist-
ence of such a stretching force is to be expected. This term
" stretching " is here used in preference to " axial force " because
the latter does not imply any particular polarity of motion, while
the former term shows that the force acts in two opposite direc-
tions so as to straighten and lengthen the conductor but not to
move it bodily; of course when one end is fixed, the other would
then move bodily. The term " tensile strain " might be used, but
it implies external forces, while the manifestations of this stretch-
ing appear as an internal force like in the pinch effect, even
though both might be explained by the action of the external
encircling magnetic flux.

The difficulty in differentiating beyond question such a
stretching force from all others, lies in the fact that the action
in almost every conceivable combination of circuits may gener-
ally also be explained by the older laws, although sometimes it
may require some skilful juggling to do so. But even assuming
that it were possible to explain all known actions by the older
laws, yet if a stretching force also explains them all, and it seems
to do so without exception, then why not use it in preference to
the others. It is far simpler to understand; the reason for its
existence (namely the mutual repulsion of the encircling lines of
force) is easily grasped by a student; a single, simple force will
then explain numerous different phenomena, which now require
a number of different laws to be learned parrot-like, because there
is no apparent reason for them; and in general it greatly simpli-
fies the teaching of some of the various electrical motive devices
and might even lead to practical applications which would not
have been suggested by the older laws.

It might be better still to explain all such phenomena by the
simple statement that a magnetic line of force always tends to
contract, that it tends to repel a neighboring line of force of the
same polarity, and to attract one of opposite polarity. A conduc-
tor with a current may then be likened to a wire surrounded by
stretched rubber bands like umbrella rings, which are also crowded
together laterally; their contraction produces that which corre-
sponds to the pinch effect, and their lateral expansion that which
corresponds to the lengthening effect. The stretching of a cur-
rent-carrying conductor then follows as a consequence, if it is
true, as it seems to be (although difficult to demonstrate directly)

that a line of force is rigid with the material of the conductor carrying the current which produces it.

The writer has frequently called attention to the fact that it is wrong to say, as is so often done in text-books, that like currents attract and unlike repel, as it is not the currents *per se* but the material of the conductor which is attracted and repelled, for otherwise Ohm's law would not hold for large conductors and the pinch effect would then not exist; this distinction is sometimes very important.

So it seems equally wrong to say that like lines of force repel and unlike attract, when it seems to be a fact that it is the material in and about which these lines of force are generated, which is moved or affected by those forces. In that case this stretching force is a consequence; so is the pinch phenomenon. It is admitted that the conception of these relations of magnetic lines of force to each other in space is very useful to the mathematical physicist and enables him to deduce very valuable conclusions; but it is also true that the other conception is a very convenient one in practice, namely that every line of force has its origin in some material body and that whenever any of these lines external to it are changed in their position by some force, that force will be felt on that material body. When the disturbing force consists of two equal and opposite ones, no resultant action would be felt by the material, but this does not disprove the original contention. Such a conception would greatly simplify our understanding of many phenomena and hence also the teaching of the student.

There is another parallel case in induction to which the writer recently called attention and which he demonstrated.[4] It is that another one of our former conceptions, so often taught, is wrong; namely, the statement that lines of force cutting a *circuit* will generate an e.m.f. It is not the circuit *per se* but the material of that circuit which must do the actual cutting; if the circuit cuts them but the material does not, there will be no induction; this was demonstrated beyond question.

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[4] A New Factor in Induction; the "Loop" *vs.* the "Cutting Lines of Force" Laws. Elec. World, Mar. 14, 1908, vol. li, p. 559. An Imperfection in the Usual Statement of the Fundamental Law of Electromagnetic Induction. Trans. Amer. Inst. Elec. Eng. 1908, vol. xxvii, part 2, p. 1341.

If, therefore, these forces act on the material, as was shown in
the pinch phenomenon in the case of the attraction of like cur-
rents, and was shown in the writer's induction experiment in the
case of the cutting of lines of force, then why should we not
expect the same law to be true in the case of magnetism; it would
seem to be unreasonable not to do so.

The following experiments, which are believed to be new, all
indicate the existence of this stretching force; it is by no means
a small force when the currents are large.   Moreover several of
them show that some of the former teachings have been wrong
and must now be modified and corrected.

In Fig. 6, *a* and *b* are semicircular troughs of mercury.   *B*
is a pivoted bridge piece connecting the two troughs and free to
move around its pivot.   The alternate ends of the troughs are
connected to a source as shown.   The mercury parts of the cir-
cuit in both troughs become longer by the clockwise motion of
the bridge; hence if the current lengthens its conductor it ought
to move the bridge clockwise.   It will be found to do so and the
force was so great as to sometimes throw the bridge off its pivot.

This lengthening is independent of the direction of the cur-
rent, hence would therefore take place equally well with alter-
nating current.   Moreover the force seems to be equally strong
for all positions of the bridge; hence is independent of the length
of the conductor.   This was, however, not measured accurately.
Theoretically it seems that when free from all external influences,
it should be independent of the length and directly proportional to
the square of the current.   Moreover the stretching should con-
tinue indefinitely, and in this respect it is different from the
stretching of a rod strained by compression.

It will be seen that this is not Ampere's classic experiment:
in the latter there was no lengthening of the circuit; moreover
his circular current was a coil, thus making the whole circular
space the equivalent of the end of a magnet, while in the present
experiment the motion seems to start with the same force when
the circular circuit begins to be formed, as it has later, hence seems
to be independent of the length and therefore of the magnetic
flux formed by the circular part of the circuit; and the currents
in the circular part are not in the same direction around the
circle.   Furthermore in Ampere's experiment the current in the
bridge piece flowed out radially from the central pivot, therefore

in the opposite direction in half of the bridge piece to that in this
experiment.   Ampere's experiment is the fundamental principle
of what is now known better as the disk unipolar machine.

The action in Fig. 6 might be shown pictorily as in Fig. 7.
In this the magnetic flux encircling the conductor is represented
by lines of force; for the same current there should be a constant
number of these lines per inch of circuit; by the lengthening of
the mercury parts of the conductor some new lines of force have
therefore been produced.   They must not be assumed to come
from some other part of the circuit, for in the rest of the circuit
they remain as they were; the new ones have been created and
are therefore to be added to the others; their generation must
produce a counter e.m.f.   It is the tendency to produce this new

FIG. 6.   FIG. 7.   FIG. 8.   FIG. 9.
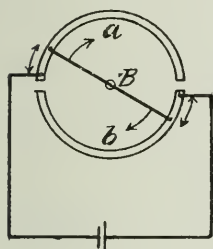
flux, or magnetic energy, which causes the lengthening; if none
is produced, there will be no tendency to lengthen.

It is not denied, however, that the present experiment shown
in Fig. 6 might also be explained by the known action of two
currents making an angle with each other; but it is not believed
that it had been so devised before that there was a direct lengthen-
ing of the circuit.   Moreover, when the ends of the bridge piece
were bent nearly horizontally in arcs over the mercury troughs for
about the distance equal to the radius, and then had their ends
dip into the mercury, the action seemed to be just the same,
even though the two currents which make an angle with each
other were then much farther apart than before.   This would
indicate that the angular motion was not the true explanation of
an apparent stretching, but that on the contrary, a real stretching
was the true explanation of the apparent angular motion.

Ampere's trough experiment Fig. 4, and the expansion of a

circular ring, as mentioned above under *c,* have formerly been explained by saying that every circuit tends to expand so as to include as great an area as possible. If this were the true explanation of the movement, it would follow that there ought to be no motion if thereby the area of the circuit is not increased. While if the true explanation is the stretching of the conductor, the circuit should go on expanding even if the area is not increased thereby.

The foregoing test, Fig. 6, showed the former to be wrong and the latter right: hence it differentiates between these two and shows that the teaching of the former should cease. It will be noticed that no matter which way the external return wires are placed, the motion of one-half of the bridge piece will decrease the total area enclosed by the whole circuit, exactly as much as the other half will increase it, hence this area will remain constant, and yet there is motion. The conception that the circuit tends to lengthen does not require this incorrect condition.

This is shown still more strikingly by connecting the external circuit, as shown in Fig. 8, using only half of the apparatus of Fig. 6. The motion will then be as shown, which will be seen to actually diminish the total area, thus giving the reverse effect to that required by the older theory. The rotary motion will be in the same direction when the connections are transferred to the other arm of the bridge and its trough; this causes the area to increase. In both cases the conception of the lengthening of the circuit predicts the correct result, while the other fails in either one or the other.

Another instructive and interesting experiment is shown in Fig. 9. Here one of the return wires to the source is placed as close as possible to the mercury trough, thus making the part *abc* of the circuit practically non-inductive. The motion will then be as shown, which at first sight would appear to be a shortening of the mercury part of the circuit; but the non-inductive part *abc* is now no longer a part of the circuit, as far as the encircling magnetism is concerned, because magnetically its effect is zero. Hence a movement from *c* to *b* really lengthens the circuit by the amount *cb,* but this time in the return part of the circuit. After this movement there is as much more flux surrounding the wire as corresponds to that increase of effective length *cb,* that is, to the decrease of the ineffective or non-inductive length.

This experiment also shows that the increase of length takes place equally well in a solid as in a liquid conductor, hence is not due to any movement of the liquid.

As the direction of motion of the bridge wire is reversed in Figs. 8 and 9 by merely bringing the return wire nearer to the trough, it necessarily follows that the return wires when very close, have some effect and that there must be some position of the return wire at which there is no further tendency to move. At this point the tendency to lengthen is exactly balanced by an equal and opposite magnetic force elsewhere in the circuit and produced by the motion of the bridge.   Thus in Fig. 10 the bridge *B* would move as shown until the tendency to lengthen the curved part of the circuit is balanced by the tendency of the angular part to straighten (as shown in Fig. 3) by the same magnetic forces as those which tend to stretch the wire.   In this position the magnetic energy of the whole circuit is greatest; the inductance
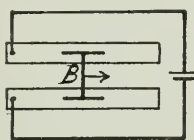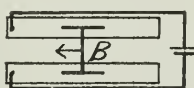
FIG. 10.	FIG. 11.	FIG. 12.	FIG. 13.
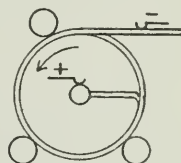
would be decreased by a motion of the bridge arm in either direction, hence is the greatest that can be produced by moving that arm.   The tendency to increase in length is then equal to the tendency of that angle to straighten out.

Another such instance is that of a bifilar non-inductive circuit, in which there should be no stretching because by doing so there would not be produced any additional flux.   In a non-inductive part of a circuit the two currents are equal and opposite, hence there is no effective current, and therefore in that sense it is not a real and effective circuit.

In the following modifications of Ampere's classic trough experiment the same results are shown.   The ordinary arrangement was shown in Fig. 4.   When the leads are brought around to the other side, as shown in Fig. 11, the motion will be in the same direction as before, thereby diminishing the area of the circuit, contrary to some teaching.   By bringing the return wires

very close to the troughs, as shown in Fig. 12, the direction of
motion is reversed.

A mechanical device with sliding contacts instead of mercury
troughs might be devised so as to give continuous rotary motion
by this stretching of the conductors, thus producing a self-starting
alternating current motor; but the large currents necessary to
produce strong forces give rise to difficulties at the rapidly moving
sliding contacts. Such a motor would have the characteristics
of a low volt machine like those of the unipolar type. Industrial
applications of this force might, however, be possible in some
electric furnaces in which large currents pass through liquid con-
ductors, and in which such a force might be used to produce in-
ternal circulation; in liquids, small forces (like differences in
densities, for instance) can be used to produce very decided
motions.

One of the curious consequences is that if this stretching force
were large enough a wire should wind itself into a coil, as shown
in Fig. 13, and thereby develop a counter e.m.f.; or conversely,
unwinding such a current carrying coil should generate more
current.

SUMMARY.—The above is believed to show: that there were
reasons to expect that a current develops an axial force in its
conductor which tends to straighten and stretch it; that experi-
ments show the existence of such a force, and that it can be
made to produce bodily motion; that while it may be possible to
explain most of the various different motions by the numerous
different older laws which must be learned by the student, this
one simple law explains them all, thus making the learning of
most of the numerous older laws unnecessary; that the reason
for the existence of such a force would be readily conceived by the
student, thereby avoiding the necessity of a parrot-like memoriz-
ing of the older laws; that some of the experimental results show
that former teachings were wrong in at least one respect; that
this stretching force enables the correct results to be predicted in
all known cases while one of our older laws predicts wrong
results; that some of the observations or deductions (as, for in-
stance, b, e, and f) cannot, it seems, be explained or are not sug-
gested by the older laws; that for the mathematical physicist the
older laws seem to suffice, but for the student and practising
engineer the conception of such a stretching force simplifies the

understanding of some of the actions of currents with which he
may have to deal; and that the existence of such a stretching force
may suggest ideas or explain phenomena which the older laws
would not.

The following conclusions seem to be true, although still
subject in part to positive and quantitative demonstration:

In a conductor free from all external influences a current
exerts a stretching force, due to its magnetic effect, which is inde-
pendent of the direction of the current or of the length of the
conductor and is presumably proportional to the square of the
current and inversely proportional to the cross section; it contin-
ues to act, no matter to what length the conductor has been
stretched by it, and is therefore not of the nature of a strain;
it is affected by neighboring currents and becomes less as these
neighboring currents neutralize the magnetic effect of the cur-
rent, being zero in a perfectly non-inductive circuit; when it pro-
duces motion a counter e.m.f. is produced; when such motion is
reversed by a stronger opposing mechanical force, a direct e.m.f.
is produced.

Standard Cement Specification. (*Eng. Record,* lxii, 14.)—
The British Standard Specification for Portland Cement has been
revised a second time by the Engineering Standards Committee,
as a result of the investigations of the sectional committee on
cement. For determining initial set the Vicat needle alone is speci-
fied, and the British Standard set aside. Clauses are inserted
regarding minimum lime content and total loss on ignition and a
provision for limiting the total amount of sulphur present whether
as sulphates or sulphides. The instructions for gauging have been
modified so as to remove any ambiguity as to the actual consistency
of the cement. The increase in tensile strength of cement and sand
briquettes is now graded in a similar manner to that of neat cement
briquettes.

Testing Boiler Feed Water Electrically. W. POLLARD DIGBY.
(*Jour. Inst. Elec. Eng.,* Aug., 1910.)—This test is based on the
fact that pure water is an imperfect electrical conductor, but if
small quantities of salts are dissolved in it the conductivity is greatly
increased, in proportion to the quantity of salts. Hence by passing
a current through a tube of definite dimensions with platinum elec-
trodes, and reading the resistance by an ohm-meter, the conductivity
is a measure of the total salts in solution.

Rotating Graphite Anode. J. W. Turrentine. (*J. Ind. Eng. Chem.,* ii, 342.)—The author has designed a satisfactory graphite anode for use with the graphite cathode dish. It is in the form of a dish, 4 cm. deep with walls 2 to 3 mm. thick, cylindrical for 2 cm. of its depth and then a truncated cone narrowing from 8 to 3 cm. In the bottom is a hole 1.2 cm. in diameter and four equidistant radial slits in the sloping portion of the side. It is supported for rotation by the outward pressure on its inner wall of three aluminum prongs attached to the rotating shaft. Rotation brings the bulk of the solution between the cathode dish and the outer walls of the anode. In such electrolyses the anodic oxygen does not pass over and tend to oxidize the metal on the cathode. The porosity of the graphite is greatly reduced, without notably impairing the conductivity, by treatment with paraffin or ceresin, while the tendency to flake is not conspicuous except at fairly high current densities, such as 6 ampères per square d.c.m.

Electric Steel Refining. D. F. Campbell. (*Iron Age,* lxxxvi, 15.)—In the electric furnace almost any degree of refining can be economically effected and the removal of sulphur, phosphorus and oxygen is especially easy. This is probably due to at least three causes:

1. The intense heating of the slag, which is the place where refining occurs, owing to the high temperature and the extreme fluidity of the slag, the rate of the reaction is very great, because the velocity of the reaction rises very quickly for high temperatures, and not in direct proportion to the temperature.

2. The extremely basic slag that can be kept in a very fluid state. and the calcium carbide formed by the action of the arc on the calcareous slag, are especially advantageous for de-sulphurization.

3. The violent motion of the steel. resulting from the convection currents produced in the bath, due to the two intensely hot areas caused by the arcs below the electrodes, increases the volume of steel exposed to the hot and fluid slag area—hence the rate of refining.

Ferrotitanium in Steel and Iron Castings. Leonhard Treuheit. (*Iron Age,* lxxxvi, 12.)—Mr. Treuheit. superintendent of the Yaeger Iron and Steel Works of Elberfeld, Germany, controverts the statements of firms selling ferrotitanium and similar alloys on the following points. based on factory experience : 1. That ferrotitanium alloys do *not* raise the temperature as claimed. 2. The fracture photographs show that the claim that these alloys produce a finer structure is incorrect. 3. That they do *not* reduce sulphur. 4. That the use of these alloys is not economical in comparison with other purifiers, such as, for instance, aluminum.

THE INFLUENCE OF CHEMICAL AFFINITY IN CER-
TAIN PHENOMENA CALLED ADSORPTION.

BY

M. LÉO VIGNON.

(Translated from *Comptes rendus,* cli, No. 16, by W. J. Williams, F.I.C.)

IF a solid surface be in contact with a heterogeneous fluid-medium, either liquid or gaseous (a solution or a mixture of solids, of liquids, of gases, or of vapors) adsorption takes place, and can be measured by the changes of composition to which the liquid or gaseous medium is subjected under the influence of this solid surface.

It has long been known that in all substances a force is manifested between the particles, which has been called *molecular attraction,* on account of the special meaning which chemists give to the word *molecule.* This attraction, quite distinct from universal attraction, is characterized by the fact that it is exerted between certain particles, and only at very small distances, comprised in an extremely limited field. It may be added that this particular attraction causes the phenomena of cohesion, adhesion, friction, capillarity, viscosity, and surface tension, that it is very strong in solids, weaker in liquids and almost negligible in gases.

In the study of the phenomena of adsorption, it is evidently necessary to recognize the physical condition of the body under consideration, and in particular to determine if the substances mixed with the fluids are *actually* dissolved. In fact, if the solid surface is in contact with a liquid in the conditon of a false solution, or with a gas holding a liquid or a solid in suspension, the undissolved solid or liquid particles will attach themselves to the solid surface by the mere effect of this particular attraction.

I have given examples of this order of phenomena in showing that sand and asbestos fix the coloring matters in a colloidal solution ("Adsorption of Certain Coloring Matters," *Comptes rendus,* July 4, 1910).

These experiments were carried out by taking river sand and asbestos as the solid surfaces, that is to say, substances almost inert from the chemical point of view.

I have sought to determine whether the *chemical nature* of
the solid surface had any influence on the phenomena of ad-
sorption.

With this end in view, for chemically inert solid surfaces
I substituted chemically active solid surfaces, notwithstanding
their insolubility, the chemical activity of these surfaces being
deduced from their chemical composition.

I have the honor of presenting the results thus obtained to
the Academy of Science.

The solid surfaces employed, chosen for their chemical ac-
tivity, were silica, alumina, zinc oxide, silk, and asbestos (as a
standard).

On these surfaces, well washed with distilled water, there
were permitted to react aqueous solutions containing one one-
thousandth of coloring matter *actually dissolved* (picric acid,
fuchsine S, see *Comptes rendus,* July 4 1910).

Two series of experiments were made, the first by filtration,
the second, by prolonged contact.

1. *Filtration.*—Twenty-five c.c. of the colored solution were
passed at the ordinary temperature over a cylindrical column,
0.01 m. in diameter and 0.20 m. high, of the adsorbing matter
in powder or in filaments. I determined the coloring matter in
the liquid drained off.

FIXATION OF THE COLORING MATTER, IN 1/1000 AQUEOUS SOLUTION, PER 100
PARTS OF ADSORBENT MATTER.

ADSORBENT MATTER.	PICRIC ACID.	FUCHSIN S.
Calcined silica 0.00		0.00
Hydrated silica 0.00		0.21
Hydrated alumina 1.10		1.18

By this method the period of contact was very short (1 to 2
minutes). I then passed on to experiments of longer duration.

2. *Prolonged Contact.*—One Gm. to 2 Gm. of the solid sub-
stance, in powder boxes of 250 c.c. capacity closed by emery stop-
pers, were placed in contact with 200 c.c. of a one-thousandth
aqueous solution of fuchsine S, acidulated with 5 parts per 1000 of
H_2SO_4. Contact was renewed by agitation every 30 minutes,
the amount of adsorption was estimated at the end of 2, 3, and
4 days, the mixture being kept at ordinary temperature.

ADSORPTION OF FUCHSIN S IN AN AQUEOUS SOLUTION OF 1 PER 1000, PER 100 PARTS OF ADSORBENT MATTER.

ADSORBENT MATTER.	AFTER 2 DAYS.	AFTER 3 DAYS.	AFTER 4 DAYS.
Asbestos, 2 Gm. 0.03		0.11	0.11
Zinc oxide, 1 Gm. 3.84		5.45	5.45
Hydrated silica, 1 Gm. 0.06		0.06	0.06
Hydrated alumina, 1 Gm. .. 4.02		4.02	4.02
Calcined silica, 1 Gm. 0.06		0.06	0.06
Scoured silk, 0.99 Gm. 6.26		7.91	7.91

These results are plainly significant; the almost chemically inert substances (asbestos) did not fix, so to speak, coloring matters actually dissolved; it was the same with silica. Alumina, zinc oxide, and silk, on the contrary, show a notable adsorption, when the period (duration) of contact is sufficiently long.

To summarize: Insoluble solid matter, but with definite chemical functions, will or will not fix actually dissolved coloring matter, according to the chemical functions they possess.

These results agree with those of Briggs (*Journal of Phys. Chem.*, 1905, ix, 617). Thus quartz, an insoluble and acid body, adsorbs alkaline hydrates and carbonates; while sodium, magnesium and ammonium chlorides do not undergo adsorption.

It must, then, be admitted that chemical affinity is the force which determines on certain surfaces, the fixation of certain substances actually dissolved in fluids (liquid or gaseous) and in contact with these surfaces.

In this way the phenomena may be explained as shown by Briggs with quartz and by myself with alumina, silica, zinc oxide and different textiles.

The phenomenon, called adsorption, in a word, includes two quite distinct cases; bodies in false solution or in suspension are fixed by this particular attraction; those which are actually dissolved, obey the laws of chemical affinity.

It may be observed, further, that most bodies exercise a chemical action upon each other at the ordinary temperature; this is very marked in non-saturated compounds, such as carbon monoxide; but in the saturated compounds this chemical action may be very weak, scarcely perceptible, but seldom absent. It is obvious that the different atomicities which are saturated are not equal quantitatively; in a saturated compound there generally

remains a residue of activity capable of showing itself in a certain sense. The existence of numerous molecular combinations, and the fixation of water by cell-bodies in contact with the atmosphere, appear to demonstrate the existence of this activity.

Segregation in Soft Steel Ingots. G. B. W. (*Iron Age*, lxxxvi, 13: From a paper by Prof. Wust and Herr Felser in *Metallurgie* for June 22, 1910.)—This article is well illustrated and goes into detail as to the influence the segregation in soft steel has on the mechanical properties of round bars rolled from the ingots. The amount and distribution of the segregation is shown by analyses.

Sulphur and phosphorus segregate the most, carbon, manganese and copper in a lesser degree. Sulphur shows more segregation in large ingots; phosphorus, carbon and manganese show the reverse. The influence of segregation is not considerable on the tensile tests, but it affects the ductility. The greatest effect is visible in the shock tests, the segregated material being very unreliable and brittle.

Strength of Chains. (*Amer. Mach.*, xxxiii, 37.)—A convenient and reasonably accurate rule for estimating the safe working strength of a chain is: Express the diameter of the wire or bar of which the links are made in 16ths of an inch. Square this number and multiply it by 80, gives the safe working load in pounds. Thus for a chain made of ½ inch. wire:

$$8 \times 8 = 64 \times 80 = 5120 \text{ lbs., safe working load.}$$

The proof test of ½ inch chain is 7500 lbs., approximately 50 per cent. over safe working load.

Cassava and Other Succulent Vegetables. C. C. Moore, Washington, U. S. A.—Mr. Moore has patented a process for manufacturing starch from these vegetables. The finely comminuted cassava is sprinkled with a solution of sulphurous acid or of a sulphite, such as calcium bisulphite, preferably in the proportion of 10 lbs. of calcium bisulphite per ton of material, and then dried. This prevents or restrains deleterious changes due to enzyme actions and thus preserves the full content of starch and sugars in the cassava, and also converts the less dense starch granules into a denser form and thus increases the yield of marketable starch. The dried product is worked up by the usual methods, and the separated starch liquor is utilized for the production of sugars or alcohol.

THE APPLICATION OF THE ARCHIMEDEAN PRIN- CIPLE TO THE EXACT DETERMINATION OF GASEOUS DENSITIES.

BY

MESSRS. A. JAQUEROD and M. TOURPAIAN.

(Translated from *Comptes rendus*, cli, No. 16, by W. J. Williams, F.I.C.)

THE hydrostatic method has not been used hitherto, at least for exact measurements, for the determination of the density of gases. We will describe in this article an apparatus of great precision based on the principle of Archimedes, and which avoids several inconveniences inherent to the methods generally used.

A cylindrical glass float, about 200 c.c. in volume, calibrated exactly, is suspended vertically, by a platinum wire, from the beam of a balance and balanced by a suitable counterpoise; the float is enclosed in a glass tube of slightly larger size, in which it can swing freely; at the top this tube ends in a capillary tube through which the platinum wire passes, and the gas is admitted by means of a second capillary tube fused to the lower end. The whole is kept at a constant temperature by means of a water bath, in which an accurate thermometer is immersed and it is provided with a stirrer.

The carefully purified and dried gas, is introduced into the apparatus at a speed of about 1 litre per hour; little by little it displaces the air, and the weighings may be begun some hours after starting the flow of gas, and can be repeated continuously as long as the gaseous flow lasts.

At the moment of weighing the current of gas is interrupted, the diffusion of the external air takes place very slowly on account of the apparatus used, and the equilibrium position of the balance is determined by the ordinary method of oscillations. Barometer is read simultaneously with temperature of the bath.

To calculate the pressure exerted on the float by a given gas, and from that the density of the gas, it is first necessary to know the tare, *i.e.*, the weight of the float, in a vacuum. As it is impossible to weigh it directly in a vacuum, this determina- tion is made by the aid of two gases, oxygen and hydrogen,

whose density, or rather the mass of one litre under normal conditions is known exactly. We have thus obtained, as will be seen later, two series of very concordant measurements.

When working with a gas denser than air, oxygen for example, the interruption of the flow can be made without inconvenience during a time sufficient to observe the equilibrium position of the balance. In the case of hydrogen, on the other hand, it is no longer so, and immediately the gas stops, a progressive increase of the pressure is set up, due to the external air replacing hydrogen. We were then compelled to weigh without interrupting the flow of gas, and from that time the constancy remained perfect. A correction is necessary on account of the dynamic effect, which is actually very slight. We obtained this by the following method:

The hydrogen was prepared electrolytically, in such a way that an ampere meter placed in the electric circuit gave, in a relative measure, the exact flow of gas. Weighings were made with decreasing intensities and the values extrapolated to an intensity of zero, corresponding to the complete stoppage of the gas. Thanks to the smallness of the correction,—besides this function is almost linear to the current,—this device gave very satisfactory results.

The oxygen and hydrogen used in these researches were prepared by the electrolysis of a solution of potassium hydroxide and purified by passing through a tube heated to 350° C., containing platinized asbestos, then dried over sulphuric acid and phosphorus pentoxide.

Here is a summary of the results obtained. The numbers below represent the tare of the float in a vacuum: each is the mean of a large number of weighings. In this series the temperature varied from 15° to 16° C., and the barometric pressure between 715 mm. and 725 mm.

THE TARE DETERMINED BY MEANS OF:

OXYGEN.			HYDROGEN.
0.18260	0.18267	0.18265	0.18263 Gm.
0.18268	0.18255	0.18265	0.18264 Gm.
0.18266	0.18257	0.18258	0.18263 Gm.
0.18265	0.18264	0.18260	0.18268 Gm.
0.18256	0.18263	. . . . . .	0.18262 Gm.

Mean (oxygen) . . . . 0.18262   Mean . . . . 0.18264 Gm.

The agreement of the individual measurements is better in hydrogen than in oxygen, which is easily explained; in fact the pressure of hydrogen is 16 times weaker, and the errors of temperature and pressure have 16 times less influence than is the case with oxygen.

The advantage of weighing in hydrogen consist in this, that it is almost equivalent to weighing in a vacuum; the pressure of the gas in fact only amounts to hardly 2 cg., and the uncertainty as to the absolute value of the mass of a litre of hydrogen only plays an insignificant rôle.

The determinations, taken as a whole, do not then permit the calculation of the relation of the densities $\frac{O}{H}$, but they give a new confirmation of the value adopted for the mass of the normal litre of oxygen, say 1.4290 Gm., a confirmation which is correct to about one ten-thousandth.

Chemical Action of Ammonium Persulphate. A. Schuller. (*Phot. Rundschau,* xxiv, 161.)—The ammonium persulphate penetrates the gelatin and slowly changes the silver to silver sulphate, which is converted into persulphate by the excess of ammonium persulphate. The silver persulphate is much more energetic than the ammonium persulphate and attacks the silver of the image to form silver sulphate, which is converted as before. Thus the active agent in the reduction is silver persulphate, the ammonium salt merely serving to convert the silver sulphate into silver persulphate. The action is slight in the shadows of the negative, not merely because the concentration of the silver persulphate is less there than in the denser parts of the plate, but because silver persulphate hardens the gelatin and can diffuse more rapidly into the mass of liquid where the hardening effect is slight. Hence the action of the persulphate reducer is due to the varying diffusibility of silver persulphate.

The Corrosion of Iron. J. N. Friend. (*Engineering,* lxxxviii, 531.)—Only two theories of corrosion merit attention, the acid and the electrolytic theory. Pure iron, oxygen, and water may be in contact an indefinite time without mutual action; the presence of acid is necessary to cause rusting, the acid acting as a catalyzer. Generally CO_2 is the acid present. A very small quantity of CO_2 forms $FeCO_3$ or $FeH_2(CO_3)_2$, which is decomposed and forms rust by the oxygen of the air, setting free CO_2 to begin the cycle again. The various experiments which appear to show that pure water, oxygen, and iron combine to form rust are due to the fact that the water used is not pure.

Pickling Castings and Dips Used. (*Amer. Mach.,* xxxiii, 34.)—Cast-iron is poured at such high temperatures that it is impossible to prevent the adherence of sand and the formation of scale from the combination of iron oxide and sand. This is removed by pickling. The pickle is generally sulphuric acid, sometimes hydrochloric acid. Now foundries are commencing to use hydrofluoric acid which attacks the sand, but only affects the iron very slowly. The usual strength is 1 part of hydrofluoric acid to 10, 15, or 20 parts water, according to conditions. The tanks are made of oak lined with asphaltum, and the dipping baskets of hard rubber, wood fibre or wood, and should have no metal whatever. The speed is hastened by heating the bath to 150° F. by a steam-pipe. A special dip for electro-galvanizing is made by adding to the dilute acid one-half pound of sheet-zinc to each 25 gallons, adding more as it works out.

Bright dip, to bring the work out white:

>   Hydrofluoric acid .... 24 oz.,
>   Nitric acid .... 10 oz.,
>   Metallic zinc .... 2 oz.,
>   Water .... 2 gallons.

Satin finish dip:

>   Hydrofluoric acid .... 1 part,
>   Water .... 3 parts,

then dried and run through the bright dip.

Bright dip for copper, brass, bronze, or German silver:

>   Hydrofluoric acid .... 4 quarts,
>   Nitric acid .... 3 quarts,
>   Common salt .... small handful.

Another satin dip is:

>   Hydrofluoric acid ...... 2 parts,
>   Nitric acid .... 1 part,
>   Hydrochloric acid ...... ½ part,
>   Water .... 5 parts,

then rinse, dry, and run through the bright dip. Or

>   Hydrofluoric acid ...... 2 parts,
>   Nitric acid .... 1 part,
>   Water .... 10 parts.

Cementation of Iron by Solid Carbon. G. CHARPY AND S. BONNEROT. (*Comptes rendus,* cl, 173.)—Cementation of a soft open-hearth steel in a tube by means of solid carbon was attempted. The tube was exhausted by a mercury pump. There was no absorption of carbon. Endeavors will be made to determine if carbon once absorbed will diffuse under such treatment.

FRANKLIN INSTITUTE.

AWARD OF THE ELLIOTT CRESSON MEDAL TO DISTINGUISHED SCIENTISTS.

Ever since its foundation, one of the most important branches of the Institute's work has been the examination of new inventions for the guidance and encouragement of inventors, conducted by its Committee on Science and The Arts, on whose recommendation the Institute bestows awards for inventions or discoveries of signal merit. Without any formal measures the spirit in which the work of this committee is conducted has broadened, in keeping with the march of progress and advance of scientific knowledge, to the consideration of the basic advances and their general value in adding to material progress rather than the recognition of specific variations and new forms of appliances or materials already known.

There is a handful of men distributed over the four quarters of the civilized world whose first thought and labors are devoted to the solution of the problems of pure and applied science. Their work is seldom of a character that is embodied or can be represented by material results. Their achievements clear the way for the lesser task of specific application by others to whom generally come the credit and the reward. It is, therefore, consistent with the aims of the Institute and fitting to the already tacitly established functions of the Committee to recognize obvious additions that such men have made to the fund of human knowledge. Accordingly at the meeting of 5th October, 1910, the principle was formally adopted of recognizing the life-work of scientists and technologists of long established reputation by according to such scientists and technologists the highest awards of the Institute. By unanimous adoption the resolution was made to award for distinguished, leading and directive work in their respective fields the following named eminent scientists and technologists:

Sir Joseph J. Thomson,	Dr. John A. Brashear,
Prof. Ernest Rutherford,	Mr. John Fritz,
Sir Robert A. Hadfield,	Dr. Edward Weston,
Dr. Harvey H. Wiley.	

Sir Joseph John Thomson, M.A., D.Sc., LL.D., F.R.S., Cavendish Professor of Experimental Physics, Cambridge University, England.

Sir Joseph J. Thomson was born in England in 1856. He was graduated from Trinity College as Second Wrangler, became a Fellow in the college in 1880 and a lecturer in 1883.

Both as an investigator and as a writer he has made an enduring name for himself. Among his published works are "A Treatise on the Motion of Vortex Rings," 1884, "The Application of Dynamics to Physics and Chemistry," 1886, "Recent Researches in Electricity and Magnetism," 1895, "Discharge of Electricity through Gases," 1903. As may well be

supposed, Sir. J. J. Thomson, who is in the prime of life, is a frequent contributor to scientific journals. The investigations which resulted in his lectures on "Electricity and Matter" delivered at Yale University have been continued and one needs to be a persistent reader of the *Philosophical Magazine, Nature,* and other scientific publications to keep in touch with the investigations he is now making. Not the least of his important work has been that of establishing at Cambridge of a School for Physical Research that has become known throughout the scientific world. This school has become known not only through the character of the research work done in it, but through the men who have gone out from it and are now leading in the scientific thought and teaching of the day.

ERNEST RUTHERFORD, F.R.S., M.A., D.Sc., LL.D., PROFESSOR OF PHYSICS, OWENS COLLEGE, VICTORIA UNIVERSITY, MANCHESTER, ENGLAND.

Professor Ernest Rutherford was born in New Zealand in 1871. There he received his preliminary education. He then went to England and in 1893 was graduated from Cambridge University with first-class honors in Mathematics and Physics. He received the degree of D.Sc. from Trinity College, N. Z., in 1901 and in 1904 delivered the Bakerian lecture before the Royal Society. In 1898 he was appointed Macdonald Professor of Physics in McGill University, a position which he filled until 1907. It was while at McGill University that he published "Radio-Activity" and "Radio-Active Transformation." This latter book was the final form given to the third course of Silliman Memorial Lectures which he delivered at Yale University in 1905.

The work of Professor Rutherford in the investigations of radio-activity has made the entire scientific world his debtor.

SIR ROBERT A. HADFIELD, D.Sc., LL.D.

Sir Robert A. Hadfield was born in Sheffield in 1859. He was educated at the Collegiate School and received unusual parental encouragement in pursuing his natural scientific bent. At the age of fifteen he went into the laboratory at his father's works at Attercliffe intending to specialize in that department. After a year or two through the ill health of his father much of the burden of the management of the works devolved upon the son and eventually he assumed entire charge. That position he has continued to hold with remarkable effect upon the fortunes of the firm, the progress of which has been uninterrupted.

As summarizing Sir Robert's contributions to the science of metallurgy, it is of interest to present the following list of some of his best known papers: "Manganese in Its Application to Metallurgy (manganese steel)"; "Some Newly Discovered Properties of Iron and Manganese"; "Manganese Steel"; "Alloys of Iron and Silicon"; "Alloys of Iron and Aluminum"; "Alloys of Iron and Tungsten."

The high esteem in which he is held among scientific men has been frequently attested by the conferment of honors both at home and abroad.

The Hadfield Steel Foundry is an impressive testimonial to the energy and enterprise of a great manufacturer but an incomplete one, for he has in various ways played a notable part in the industrial life of Sheffield.

JOHN A. BRASHEAR, Sc.D., LL.D.

Dr. Brashear was born in Brownsville, Pa., in 1840. During his early career he became identified with the iron industry and for many years held the post of Master Mechanic in rolling mill operations. Early in life he became interested in astronomical pursuits, an interest which he maintained throughout his association with the iron industry and eventually led him to engage in the manufacture of optical and astronomical instruments. The many articles on astronomical subjects which Dr. Brashear contributed to the daily press enlisted the interest and aid of Mr. William Thaw who furnished the means to build and equip a better workshop for the manufacture of optical instruments than was then available. To this unsolicited aid Dr. Brashear attributes much of his early success. In 1881 in association with Mr. James B. McDowell the present plant was organized. Among the instruments he constructed which have secured an epoch making place in scientific investigation may be mentioned the speculum plates for the famous diffraction gratings of Professor Rowland, the optical parts of the equally famous interferometer of Professor Michelson and the bolometer, an instrument capable of measuring incredibly small changes in temperature.

Dr. Brashear was formerly Director of the Allegheny Observatory and Acting Chancellor of the Western University of Pennsylvania. He has been recipient of degrees and honors at home and abroad from a number of colleges and scientific societies.

JOHN FRITZ, ESQ.

Mr. Fritz was born in Chester County in 1822. At the age of sixteen as a blacksmith's apprentice he gained his first acquaintance with the manufacture of iron at a charcoal blast-furnace to which he had been sent to do some repair work. In 1845 he went to Norristown, Pa., and assisted in building what was then considered the best mill in the country for making bar iron. He was soon afterward placed in charge of this mill.

In 1854 he went to Johnstown to direct the rebuilding of the rail mill of the Cambria Iron Company. Here in 1857 he built the first three-high rail mill ever built in the face of strong opposition both of the workmen and of some of the owners of the mill.

In 1860 he became General Superintendent of the newly organized Bethlehem Iron Company, which position he held for over thirty-two years, practically creating a plant which for many years occupied a unique as well as a leading position in the metallurgical industries.

He is honorary member of the Iron and Steel Institute of Great Britain, from which he received the Bessemer Gold Medal for services in the advancement of steel manufacture. He is an honorary member of

the American Society of Civil Engineers and Life Member and Past
President of the American Society of Mechanical Engineers. He is also
President of the American Institute of Mining Engineers and is an honorary
member of the Franklin Institute.

EDWARD WESTON, D.Sc., LL.D.

This distinguished inventor and electrician was born at Brynn Castle
near the town of Oswestry, Shropshire, England, on May 9, 1850.

As a boy he was a close student of electricity. His parents desired
him to study medicine, but after three years he abandoned his studies
and came to America, where after some effort he secured a position
with the American Nickel Plating Company. By his efforts both the
company's interests prospered and the state of the art was greatly improved.

In the year of 1872 he began exhaustive study and experimental
investigation of the dynamo-electric machine. His most active work
dates from the time of the formation of a copartnership in the year of
1874 with the firm of Stevens-Roberts and Havell of Newark, New Jersey.

In the fourteen years from 1872 to 1886 Dr. Weston accomplished an
extraordinary amount of work on the problems before him and in eleven
years three hundred (300) patents on numerous useful applications of
electricity had been issued to him.

In 1886 he established the laboratory at Newark where were originated
the Weston electrical measuring instruments now used the world over
and the equally famous Weston Cadmium Cell and the zero coefficient
resistance alloy "Manganin."

The works of the Weston Electrical Instrument Company at Newark,
New Jersey, where the Weston products are now manufactured, is the
largest and most complete factory of the kind in the world.

Dr. Weston is charter member and Past President of the American
Institute of Electrical Engineers. He is Trustee of the Stevens Institute
of Technology and an Honorary Member of the Tau Beta Pi Fraternity.
He is also member of many other societies here and abroad.

HARVEY W. WILEY, M.A., M.D., PH.D., LL.D.

Aside from Dr. Wiley's well known and valued work in the field of
agricultural chemistry, a work which makes all those interested in agri-
culture, directly or indirectly, his debtors, his aggressive work in minimizing
the effects of harmful preservatives in food and drink has commanded
the attention not only of the public but of medical societies as well.

Dr. Wiley was born at Kent, Indiana, October 18, 1844. He was
graduated from Hanover College in 1867 with the degree of Ph.D. and
from Harvard in 1873 with the degree of LL.D. He held the chair of
Professor of Chemistry at Purdue University from 1874 to 1883. During
the latter part of this period from 1881 to 1883 he served as State Chemist
of Indiana. He has also served as delegate to various congresses and
occupied other posts of importance.

In 1883 he became chief of the Bureau of Chemistry, United States Department of Agriculture, a position which he has filled with the highest credit to himself and in which he has earned the lasting gratitude of a nation.

PRESENTATION OF ELLIOTT CRESSON MEDAL

TO

JOHN A. BRASHEAR, D.Sc., LL.D., F.R.A.S.

At a special meeting on Friday evening, December 9, 1910, Professor Brashear delivered a lecture on " Contributions of Photography to Our Knowledge of the Stellar Universe."

This meeting was made the occasion for the presentation to him of the Institute's Elliott Cresson Medal for his distinguished contributions to astronomical science. In presenting the medal the President of the Institute, Mr. Walton Clark, said:

" Ladies and gentlemen, members and friends of Franklin Institute,— we have gathered in this historic hall of our venerable Institute, to present to John Alfred Brashear, Doctor of Science, Doctor of Laws, Fellow of the Royal Astronomical Society—eminent and honored as engineer, scientist, astronomer, educator, craftsman and man, the highest honor in our gift— the Elliott Cresson Medal.

" We do this upon the following recommendation of our Science and Arts Committee:

" This Committee recommends that the Elliott Cresson Medal be awarded for ' distinguished leading and directive work in the production and perfection of instruments for astronomical research ' to John A. Brashear, Sc.D., LL.D., of Pittsburg, Pa.

" Dr. Brashear, I am honored in being the medium through which The Franklin Institute conveys to you its Elliott Cresson Medal and accompanying certificate."

After expressing his thanks for and appreciation of the honor conferred, Professor Brashear described the methods and apparatus employed in modern astronomical research and the recent important advances in astronomical knowledge, made possible by the applications of photography to this field of work. The lecture was illustrated by a large number of interesting and beautiful photographs of nebulæ, star clusters and other heavenly bodies.

PRESENTATION OF ELLIOTT CRESSON MEDAL

TO

EDWARD WESTON, D.Sc., LL.D.

The Elliott Cresson Medal recently awarded by the Franklin Institute to Dr. Weston for his achievements in Electrical Science was presented to him by the Secretary of the Institute on the evening of December 16, at a dinner given at The Lotos Club, New York City.

In presenting to Dr. Weston the Elliott Cresson Medal Dr. Owens said:

"Dr. Weston, by virtue of authority delegated to me, I present to you on behalf of the Franklin Institute of the State of Pennsylvania, the Institute's Elliott Cresson Medal and accompanying certificate in recognition of your brilliant and successful researches in the field of electrical discovery, and also in recognition of the indomitable energy you have so lavishly and so effectively expended throughout a period of nearly half a century in the advancement of the applications of electricity to fill the needs of and supply the wants of an ever increasingly complicated and exacting civilization.

"Speaking for myself, I think that you know, Dr. Weston, that I deeply appreciate the honor of being even the humble means of transmitting to you this award, and it is due to you, Sir, to say that from no one have I drawn greater inspiration in the past, and certainly no one has lent me such assistance as you have in a twenty-year effort to educate young men in this country and elsewhere to a sound understanding of the principles of science and their application in engineering."

A number of speeches were made by those present, expressive of gratification at the action of the Institute in recognizing the worth of Dr. Weston's work and expressive of the high individual opinion held, not only of Dr. Weston's efforts to advance electrical science, but also of his many personal qualities which have endeared him so greatly to his numerous friends.

Those invited to be present on the occasion included: Dr. Louis Duncan, formerly of The John Hopkins University, Past President American Institute of Electrical Engineers, and Honorary Member of the Franklin Institute; Dr. Francis B. Crocker, Prof. of Electrical Engineering, Columbia University, also Past President of American Institute of Electrical Engineers; Prof. Charles F. Chandler, Emeritus Professor of Chemistry, Columbia University; Prof. Cyrus F. Brackett, Emeritus Professor of Physics, Princeton University; Mr. Gano Dunn, Chief Engineer, Crocker-Wheeler Electric Co.; Mr. L. A. Osborne, Vice-president, Westinghouse Electric & Manufacturing Company; Dr. Charles P. Steinmetz, General Electric Company; Mr. William Stanley; Mr. John J. Carty, Chief Engineer, American Telephone & Telegraph Company; Mr. Charles W. Price of the *Electrical Review;* Mr. W. D. Weaver of the *Electrical World,* Mr. Samuel Insull, President, Chicago Commonwealth Company, Dr. S. W. Stratton, Director, U. S. Bureau of Standards; Colonel Samuel Reber, Signal Corps, U. S. A.; Prof. D. C. Jackson, Massachusetts Institute of Technology, President of the American Institute of Electrical Engineers; Ralph W. Pope, Secretary, American Institute of Electrical Engineers, Honorary Member of The Franklin Institute; Mr. W. C. L. Eglin, The Philadelphia Electric Company; Dr. Alexander C. Humphreys, President, Stevens Institute of Technology.

PRESENTATION OF THE ELLIOTT CRESSON MEDAL

TO

HARVEY W. WILEY, A.M., M.D., PH.D., LL.D., CHIEF CHEMIST,
U. S. DEPARTMENT OF AGRICULTURE.

Dr. Wiley kindly consenting to address the Institute at its regular stated meeting December 21, 1910, on "The Applications of Chemistry to Public Welfare," his visit to the Institute was made the occasion for the presentation to him of the Institute's Elliott Cresson Medal and accompanying certificate, for his distinguished services in the field of applied chemistry, by the President of the Institute, Mr. Walton Clark. Mr. Clark read the following resolution of the Committee on Science and The Arts:

" This Committee recommends that the Elliott Cresson Medal be awarded for ' distinguished leading and directive work in the fields of agricultural and physiological chemistry ' to Harvey W. Wiley, Esq., M.D., Ph.D., LL.D., Chief Chemist of the Department of Agriculture, Washington, D. C."

Addressing the audience, Mr. Clark said:

"The services of Dr. Wiley in the cause of science and for the good of his fellow citizens and the inhabitants of the world generally are too well known to need any comment, and I will not dwell upon them. Dr. Wiley's record as a scientist is in part covered by the statement which I have in my hand, but even it is so long that I will not detain you by mentioning more than a few of the many honors and recognitions he has received. Dr. Wiley is Professor or Consulting Professor of Chemistry in several of our large universities, is Chief Chemist of the U. S. Department of Agriculture, is President of The American Therapeutic Society, Vice-president of The Society of Chemical Industry, Chairman of The Board of Food and Drug Inspection; has represented the United States in numerous international congresses and expositions, and is a member or honorary member of some thirty to forty national and international scientific associations. His decorations include Chevalier Merite Agricole, Chevalier Legion d' Honneur."

To Dr. Wiley Mr. Clark said:

" The Franklin Institute gratifies and encourages its friends by this evidence that it appreciates work of a high scientific and beneficent character, and that it recognizes in you a natural recipient for the highest honor it has to confer; and I am pleased, indeed, to be associated with the transfer to you of this evidence of the Institute's appreciation of the high merit of your work—the Elliott Cresson Medal and certificate."

FRANKLIN INSTITUTE.

(Proceedings of the Stated Meeting, held Wednesday, December 21, 1910.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, December 21, 1910.

PRESIDENT WALTON CLARK *in the Chair.*

The Stated Meeting of the Institute was held this evening at eight o'clock.

Present 175 members and visitors.

Additions to membership since last meeting, 6.

The following nominations were made for officers and managers, to be voted for at the Annual election to be held January 18, 1911:

For *President* (to serve one year), Walton Clark.

For *Vice-President* (to serve three years), James Christie.

For *Treasurer* (to serve one year), Cyrus Borgner.

For *Managers* (to serve three years), John Birkinbine, Walton Forstall, Dr. E. Goldsmith, Louis E. Levy, Richard Waln Meirs, Coleman Sellers, Alba B. Johnson, A. P. Robinson.

For *Managers* (to serve one year), Prof. G. A. Hoadley, G. E. Kirkpatrick, Dr. Isaac Norris, Jr.

After the nominations for officers Dr. Harvey W. Wiley, Chief of the Bureau of Chemistry of the U. S. Department of Agriculture, was presented the Institute's Elliott Cresson Medal and accompanying certificate, in recognition of his distinguished leading and directive work in agricultural and physiological chemistry, by President Walton Clark, whose remarks on the occasion appear elsewhere in this issue of the JOURNAL.

Dr. Wiley was then introduced and delivered a most interesting and instructive address on the "Applications of Chemistry to Public Welfare."

After the address a unanimous vote of thanks was extended Dr. Wiley and his address referred to the Committee on Publication.

Mr. Henry A. Gardner, Director of the Scientific Section of the National Paint Manufacturers' Association, and to be after January the Assistant Director of the Institute of Industrial Research, Washington, then presented an interesting communication on the technology of pigments and their applications. The speaker described the various processes in the manufacture of paints and presented results of numerous tests made in various parts of the country on wood and metal structures. The paper was illustrated by one hundred and fifty lantern slides.

After a brief discussion a vote of thanks was tendered Mr. Gardner.
Adjourned.   R. B. OWENS,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, December 7, 1910.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, December 7, 1910.

MR. THOMAS SPENCER *in the Chair.*

The following reports were presented for final action:

No. 2426.—Welin's Life Saving Appliances on Board Ships (Scott Medal). Adopted.

No. 2503.—Bennet Typewriter (Longstreth Medal). Adopted.

The following reports were presented for first reading:

No. 2474.—Baylis' Brush Holder (Certificate of Merit).

No. 2475.—Roper Safety Propeller (Certificate of Merit).

No. 2485.—Gardner Dalite Lamp (Advisory). Adopted.

No. 2489.—Hopkins' Speedometer and Dynamometer (Longstreth Medal).

R. B. OWENS,
Secretary.

SECTIONS.

Mining and Metallurgical Section.—A meeting of· the Section was held on Thursday evening, December 1, at eight o'clock.

Mr. Thomas Spencer, temporary Chairman. Present, sixty members and visitors.

After the reading and approval of the minutes of the previous meeting the Chairman introduced Dr. Joseph W. Richards, of Lehigh University, Bethlehem, Penna., who delivered an address on " A Vacation Trip in Scandinavia with some Observations on the Electrometallurgy of Iron and Steel."

The speaker gave an interesting account of a journey through Norway and Sweden which he made during the past summer and described the various iron and steel plants of the countries. He spoke of the utilization of the streams and water-falls for power purposes and presented statistics on the cost of water power in various localities.

Numerous lantern views of Scandinavian scenery, hydro-electric plants and electric furnaces were shown during the course of the lecture.

After a brief discussion the thanks of the meeting were extended to Dr. Richards.

Adjourned.

ALFRED RIGLING,
Acting Secretary.

Section of Photography and Microscopy.—Regular meeting of the Section was held in the Lecture Room of the Institute on Thursday evening, Decem-

ber 8, at eight o'clock., Dr. Henry Leffmann in the Chair, J. W. Ridpath, Secretary. Fifty members and visitors were present.

The minutes of the previous meeting were approved as recorded and noted in the Journal of the Institute.

Mr. W. N. Jennings, of Philadelphia, exhibited a new Aero Camero of the fixed focus type, fitted with a rapid lens capable of covering sharply an 8 x 10 plate, also a multi-speed shutter sufficiently rapid to take a sharp picture from the basket of a rapidly moving balloon. The superior capabilities of this new Aero Camera were illustrated by about fifty slides, taken with a long focus camera, a Kodak, and the new Aero Camera; clearly showing the superiority of the latter in convenience and speed. It is small, light, requires no focussing, and gives sharp pictures at distances varying from a few feet to a mile or more. A flock of sea gulls on the wing taken from a rapidly moving steamer, a bird's-eye view of Philadelphia, and other difficult subjects showed this feature clearly.

Dr. Leffmann showed twelve interesting landscape views; also twenty-eight Swiss and German scenes taken by Mr. Richard Pertuch. These views were all interesting and some were quite beautiful.

No further business appearing, the meeting adjourned at 9.20 o'clock P.M.

J. W. Ridpath,
Secretary.

Mechanical and Engineering Section.—A meeting of the Section was held on Thursday evening, December 15, at eight o'clock. Dr. George A. Hoadley, temporary Chairman.

After the reading and approval of the minutes of the previous meeting the Chairman introduced Dr. S. W. Stratton, Director of the Bureau of Standards, Washington, D. C., who presented an interesting communication on "The Work of the Bureau of Standards in Connection with Structural Materials." The speaker gave an account of the purposes of the Bureau and the work done by each of its departments. Numerous problems which were presented to the Bureau for solution from time to time were described. Lantern slides of testing apparatus and related subjects were shown during the course of the lecture.

In the discussion which followed Dr. Goldsmith, Messrs. Trautwine, Hering, Cullen, Snook and others participated.

The paper was referred to the Committee on Publications and the thanks of the meeting were extended to the speaker.

Adjourned.

Alfred Rigling,
Acting Secretary.

SOME PRACTICAL OBSERVATIONS IN ALASKA.

A lecture bearing the above title was delivered in the Hall of the Institute on Friday evening, December 16, 1910, by Mr. Edward R. Taylor, of Penn Yan, N. Y.

The speaker gave an account of a journey which he made to Alaska during the summer of 1910. He described the conditions existing in that country at the present time and referred especially to the agricultural possibilities, the coal and other mines and their development, and the railroads recently constructed. Views of the Taku glacier, the White-horse Pass, Lake Bennett and other impressive scenery were shown. A detailed description was given of placer mining by the individual as well as on a large scale with streams of water under high head. The lantern slides were made from negatives taken by the speaker during his visit.

MEMBERSHIP NOTES.

Elections to Membership.

RESIDENT.

Mr. Edw. O. Warner, Railroad Supplies, Franklin Bank Building, Philadelphia.
Mr. N. Spencer Greenfield, 1962 N. Stanley Street, Philadelphia.

NON-RESIDENT.

Mr. Fritz V. Briesen, Lawyer, 25 Broad St., New York City.
Mr. Wm. T. Cutter, State Chemist, B 4418, New London, Conn.
Mr. Elijah B. Benham, Mechanical Engineer, 6 Central Ave., New London, Conn.

ASSOCIATE.

Mr. Joseph E. Gibbons, Student, 1528 Glenwood Ave., Philadelphia.

Changes of Address.

Mr. Mark B. Reeves, Wildwood, N. J.
Mr. J. B. Rumbough, No. 4 The Iowa, Thirteenth and O Sts., Washington, D. C.
Mr. R. A. Widdicombe, 5552 Lakewood Ave., Chicago, Ill.
Mr. E. F. Mason, Union Station, Pittsburg, Pa.
Mr. John P. Eaton, 6114 Spruce St., Philadelphia.
Mr. J. Snowden Bell, Singer Building, New York.
Mr. J. Allen Heany, Heany Electric Co., Flint, Mich.
M. de Teive E. Argollo, C. E., Hotel Royal, Vienna, Austria.

NECROLOGY.

RESIDENT.

Samuel B. Cawley, 1443 North Thirteenth St., Philadelphia.
Henry Reeves (Stacy Reeves & Sons, 1609–11 Filbert St.), Phila.
Craig D. Ritchie, 414 N. Thirty-fourth St., formerly president of the Real

Estate Title & Trust Company, died on December 10, in his eighty-first year. Mr. Ritchie was considered one of the best authorities in the city on the valuation of real estate, and had frequently been called on by the State and city to give expert testimony. He entered the real estate business when he was 17 years old, was foremost in the organization of the Fremont Club, and was a member of the Penn Art Club, the Pennsylvania Historical Society, and the St. Andrew's Society.

LIBRARY NOTES.

Purchases.

Oberg, Erik.—Handbook of Small Tools.

Stillman, T. B.—Engineering Chemistry (4th ed.).

Moyer, J. A.—The Steam Turbine.

California State Earthquake Investigation Commission, Report (1908-1910).

Allen, A. H.—Commercial Organic Analysis, vol. ii (4th ed.).

Hough, R. B.—American Woods (vol. xi).

Readers' Guide to Periodical Literature, vol. ii (1905-1910).

Jahrbuch für photographie und reproduktionstechnik (Eder), 1910.

National Association of Cement Users, Proceedings, vol. vi.

Cattell, J. McK., ed.—American Men of Science.

International Catalogue of Scientific Literature, eighth issue (H. Geology).

Hoyer, E. V. and F. Kreuter.—Technologisches Wörterbuch.

Mineral Industry, 1908.

Todhunter, I., and Pearson, K.—History of the Theory of Elasticity and Strength of Materials.

Gifts.

Observatoire de Zi-Ka-Wei. Bulletin des Observations de 1907, fascicule A, tome 33. Shanghai, 1907. (From the Observatory.)

American Climatological Association. Transactions vol. xxvi. Phila., 1910. (From the Association.)

Illinois Bureau of Labor Statistics. Report on the Cherry Mine Disaster. Springfield, 1910. (From the Bureau.)

American Steel & Wire Company. Catalogue and Handbook of Electrical Wires and Cables. New York, 1910. (From the Company.)

Illinois Bureau of Labor Statistics, Third Report on Industrial Accidents in Illinois. Springfield, 1910. (From the Bureau.)

Illinois Bureau of Labor Statistics, Eleventh Annual Report. Illinois Free Employment Offices. Springfield, 1910. (From the Bureau.)

Hering, Carl.—Reprints of Papers. Philadelphia, 1910. (From the Author.)

Casson, Herbert N.—The History of the Telephone. Chicago, 1910. (From the Author.)

Minneapolis, Minn., Annual Report of the Water Works Department for year ending December 31, 1909. Minneapolis, 1910. (From the Department.)

Ontario Department of Agriculture. Report of Fruit Branch for 1909. Toronto, 1910. (From the Department.)

Western Australia Statistical Register for 1908. Perth, 1910. (From the Government Statistician.)

Australasian Association for the Advancement of Science. Report of the Twelfth Meeting held at Brisbane, 1909. Brisbane, 1910. (From the Association.)

Cornell University Register for 1906-7 to 1909-10. Ithaca, 1910. (From the University.)

Chicago, Rock Island & Pacific Railway Company. Thirtieth Annual Report, June 30, 1910. Chicago, 1910. (From the Company.)

Kapillaranalyse beruhend auf Kapillaritäts und Adsorptionserscheinungen Von Friedrich Goppelsroeder. Dresden, 1910. (From the Author.)

Pennsylvania Museum and School of Industrial Art. Thirty-fourth Annual Report. Philadelphia, 1910. (From the Museum.)

Labour Department (United Kingdom) Report on Collective Agreements between Employers and Workpeople in the United Kingdom. London, 1910. (From the Department.)

Pittsburg Carnegie Free Library. Eighteenth to Twentieth Annual Reports of the Librarian, Pittsburg, n.d. (From the Library.)

St. John, N. B., City Engineer Annual Report, 1909. St. John, 1910. (From the City Engineer.)

Chicago, Burlington & Quincy R. R. Fifty-sixth Annual Report. Chicago, 1910. (From the Company.)

Japanese Imperial Mint, Osaka. Report of the Director for the year ending March 31, 1910. Tokyo, 1910. (From the Director.)

North of England Institute of Mining and Mechanical Engineers' Annual Report of the Council for the year 1909-10. Newcastle-Upon-Tyne, 1910. (From the Institute.)

Connecticut State Geological and Natural History Survey. Bulletin No. 15. Second report on the hymeniales of Connecticut by E. A. White, Hartford, 1910. (From the Survey.)

Royal Academy of Science, Amsterdam. Yearbook for 1909. Amsterdam, 1910. (From the Academy.)

Royal Academy of Science, Amsterdam. Proceedings of the Section of Sciences, vol. xii, Nos. 1 and 2. Amsterdam, 1909 and 1910. (From the Academy.

Tokyo Imperial University. Calendar for 1909-10. Tokyo, n.d. (From the University.)

Canada Agricultural Department. Reports of Experimental Farms, year ending March 31, 1910. Ottawa, 1910. (From the Department.)

Lehigh University, Register of 1909-10. South Bethlehem, Pa., n.d. (From the University.)

Master Car Builders' Association. Proceedings, vol. xliv. Chicago, 1910.
(From the Association.)

U. S. Bureau of Construction and Repair. Annual Report of the Chief for
1910. Washington, 1910. (From the Bureau.)

CATLIN, CHARLES A.—Baking Powders. Providence, 1899. (From the Rum-
ford Chemical Works.)

Institution of Civil Engineers. Minutes of the Proceedings, vol. clxxxi.
London, 1910. (From the Institution.)

National Electric Light Association. Papers and Proceedings of Convention
held at St. Louis, Mo. New York, 1910. (From the Association.)

Iron and Steel Institute, Carnegie Scholarship Memoirs, vol. ii. London,
1910. (From the Institute.)

Philadelphia Bureau of Water. One Hundred and Eighth Annual Report.
Philadelphia, 1910. (From the Bureau.)

Canada Department of Trade and Commerce. Report on Canadian Trade,
Parts 1 and 3. Ottawa, 1910. (From the Department.)

La Suede Pittoresque. Svenska Turistföreningen. Stockholm, 1910. (From
Dr. Joseph W. Richards.)

Bryn Mawr College Calendar. Bryn Mawr, 1910. (From the College.)

BOOK NOTICES.

WIRELESS TELEGRAPH CONSTRUCTION FOR AMATEURS. By Alfred Powell
Morgan, Editor Mechanical and Electrical Department of the " Boys'
Magazine." Cloth, xii + 188 pages, $7\frac{1}{2}$ x $5\frac{1}{2}$ inches with 147 illustra-
tions. D. Van Nostrand Company, New York, 1910. Price $1.50 net.

Some very interesting exploits in wireless telegraphy by the younger
generation have been recently chronicled in the daily press. The enterprise
of a boy in his early teens, president of a juvenile wireless telegraph club,
testifying in behalf of his fellow operators before a congressional com-
mittee is still fresh in the public mind. Such a display of deep interest
naturally stimulates a desire to furnish the younger amateurs and the older
ones as well with every facility to carry on their experiments to the best
advantage. The book is of an exceedingly practical character, consisting
essentially of minute directions for the construction of the component
parts of the various apparatus comprising the wireless plant, illustrated
with well executed dimensioned sketches. The author makes no attempt
to consider the principles that enter into the construction described, but
he wisely does explain in an introductory chapter by simple physical
analogies the train of actions which take place and throughout the subse-
quent description frequently touches upon, and sometimes at some length,
the reasons for the methods adopted. The book will without doubt be
welcomed by amateurs and probably by even more ambitious workers.

PHYSICAL MEASUREMENTS. By A. Wilmer Duff, Professor of Physics at the
Worcester Polytechnic Institute, and Arthur W. Ewell, Professor of

Physics in the Worcester Polytechnic Institute. Second edition, revised and enlarged with 78 illustrations. Cloth, x + 258 pages, 8½ x 5½ inches. Price, $1.50 net. P. Blakiston's Son & Co., Philadelphia, 1910.

There is always a field for a manual that legitimately lightens the task of the student by distinctly pointing out the objects sought and the best means of overcoming difficulties.

This book contains a limited number of carefully chosen experiments suitable for the laboratory work of students following the usual college course in physics. At the beginning of each topic references are given to a number of well known works and at the end questions on the salient features of the method. The explanations are clear and practical and well illustrated by diagrammatic cuts. The book conforms in size and binding with the well-known work in physics edited by the first-named author, to which it should prove a valuable companion volume.

RECENT ADVANCES IN THE CONSTRUCTION OF ELECTRIC FURNACES FOR THE PRODUCTION OF PIG-IRON, STEEL, AND ZINC. By Eugene Haanel, Ph.D., Director of Mines, Canada Department of Mines, Mines Branch. Bulletin No. 3. Paper, 76 pages 10 x 6½ inches, 13 cuts and 4 inset plates. Government Printing Bureau, Ottawa, 1910.

Since the publication by the Dominion Government in 1904 of its report on electrothermic processes of smelting iron ores and making steel, enormous strides have been made in the application of the electric furnace to metallurgical operations. The present state of the industry is set forth in a comprehensive tabular statement followed by some historical comparisons and technical notes on modern electric furnace practice, particularly that in Norway and Sweden where the absence of coal deposits and abundance of water power constitute a most inviting field for such processes. The account of the Frick induction furnace is of especial interest and promises well for this most recent and increasingly successful method of heating metals.

THE APPLICATIONS OF COLLODION EMULSION TO THREE-COLOUR PHOTOGRAPHY, PROCESS WORK, ISOCHROMATIC PHOTOGRAPHY AND SPECTROGRAPHIC WORK. By Henry O. Klein, F.R.P.S. Cloth, 126 pages, 8½ x 5½ inches, illustrated. Price, 5 shillings, net. A. W. Penrose & Co., Ltd., London, 1910.

In the practice of the three-color process of reproduction in the colors of nature and analagous processes, the employment of suitably orthochromatized plates is a critical feature. Color sensitizing can be accomplished with greater accuracy with collodion emulsion than with gelatine dry plates or the common wet plate, although for black and white line work the latter has never found an equal. It is this circumstance that has given life to the almost extinct process of collodion emulsion.

The book is theoretical and practical and describes at length the sensitizing of plates with dyes for three-color work and methods of testing them;

the making of line half-tone metzograph and tri-color negatives, as well as the production of ferrotypes, photographs on wood, lantern slides, opals, transparencies, etc. Even those who do not use the collodion emulsion process will find much useful information applicable generally to photographic work.

PUBLICATIONS RECEIVED.

The Coke Industry of the United States as Related to the Foundry. By Richard Moldenke. Bulletin 3, Bureau of Mines, Department of the Interior. Washington, Government Printing Office, 1910. 32 pages, 8vo.

Production of Iron and Steel in Canada During the Calendar Year 1909. By John McLeish, B.A., chief of the division of mineral resources and statistics. Ottawa, Government Printing Bureau, 1910. 35 pages, 8vo.

Qualitative Chemical Analysis from the Stand-point of Solubilities, Ionization and Mass Action. By J. I. Hinds, Ph.D., LL.D., Professor of Chemistry University of Nashville and Peabody College for Teachers, Nashville, Tenn. Easton Pa., Chemical Publishing Co., 1910. 266 pages, 8vo., cloth. Price, $2.00.

Royal Institution of Great Britain. Weekly evening meeting February 11, 1910, Electrical and Other Properties of Sand, by Charles E. S. Phillips, Esq., F.R.S.E., M.R.I.; April 15, 1910, The Chemical Significance of Crystal Structure, by Professor William J. Pope, M.A., F.R.S.; April 22, 1910, The Telegraphy of Photographs, Wireless and by Wire, by T. Thorne Baker, Esq., F.C.S., A.I.E.E. Three pamphlets, 8vo.

Ontario Bureau of Mines. Nineteenth annual report, 1910, vol. xix, part 1. Toronto, King's Printer, 1910. 245 pages, illustrations, plates, maps, 8vo.

Production of Coal and Coke in Canada During the Calendar Year 1909. By John McLeish, B.A., chief of the division of mineral resources and statistics. Ottawa, Government Printing Bureau, 1910.

Centenario de la Republica Argentina. Exposicion internacional de ferro-carriles y transportes terrestres. Catalogo oficial. Buenos Aires, 1910. 270 pages, 8vo.

Königliches Materialprüfungsamt der Technischen Hochschule zu Berlin. Bericht über die Tätigkeit des Amtes im Betriebsjahr, 1909. Sonderabdruck aus den Mitteilungen aus dem königlichen Materialprüfungsamt zu Gross-Lichterfelde West, 1910. 112 pages, 8vo.

Manchester Steam Users' Association, Memorandum by chief engineer for the year 1909. Manchester, 1910. 32 pages, 8vo.

U. S. Bureau of Steam Engineering. Annual report of the Chief to the Secretary of the Navy for the fiscal year, 1910. Washington, Government Printing Office, 1910. 31 pages, 8vo.

CORRESPONDENCE.

City of Bradford Education Committee.

TECHNICAL COLLEGE, BRADFORD, Nov. 21, 1910.

Principal: W. M. GARDNER, M.Sc., F.C.S.

THE EDITOR,

    THE JOURNAL OF THE FRANKLIN INSTITUTE,

        PHILADELPHIA.

DEAR SIR:

In your November issue, page 367, I find a statement in an article on "Vacuum Tube Lighting" by D. M. Moore, to the following effect:

> "All the primary colors as well as their shades, are dis-
> astrously distorted by all forms of light except that from the
> carbon dioxide vacuum tube."

To this statement I must take entire exception, since for ten years there has been on the market in this country and Europe generally, a color-matching lamp known as the "Dalite" lamp, the joint invention of Mr. A. Dufton and myself. Many hundreds of these lamps are in use here, and in Germany, France, etc., by dyers who are accustomed to match the most difficult shades by their light. It is indeed, not too much to say that all large dyehouses on this side of the water are now using them.

I shall be glad if you will publish this in your valuable JOURNAL.

Yours faithfully,

(Signed)   WALTER M. GARDNER.

Moore Light Company,
169 Malvern Street,
Newark, New Jersey.

December 3, 1910.

THE JOURNAL OF THE FRANKLIN INSTITUTE,

    PHILADELPHIA.

DEAR SIR:

I note the letter you have received from Walter M. Gardner, of Bradford, England, which refers to a statement in an article furnished by me for the November issue of the JOURNAL OF THE FRANKLIN INSTITUTE. The letter does not accurately quote from my article in that the word "disastrously" has been substituted for "seriously." However, there is no reason whatever

for changing my statement in the least. For the past quarter of a century many hundreds of various forms of artificial light have been sold, due to claims being made for them that they were suitable to be used in the matching of colors. In fact from the beginning of the electric-lighting industry workers requiring a light of proper color-values have been told that almost each new form of arc or incandescent lamp far exceeded all others in this respect. There are probably tons of printed matter making these claims to-day in this country and in Europe for various modified forms of arc and incandescent lamps, for example, Tungsten or Nernst lamps—but after giving careful attention to this matter for some years past and getting into communication in various ways with thousands of interested parties, I have yet to find a single individual who has claimed that any of these lights were entirely satisfactory.

By this it is not to be inferred that the exploiters of these various forms of light were not entirely sincere, but simply that each light was capable of satisfactorily matching certain colors, but not the whole spectrum, and secondly, because that since daylight varies in some of its colors even at the same hours of the day but under different weather conditions as much as 50 per cent. The shortcomings of all of these forms of light are most clearly shown by arranging a test that consists of rapidly throwing upon a certain piece of goods, for example, first the lighting and then either daylight or the white Moore Light.

It is an extremely fortunate scientific coincidence that the carbon dioxide used in the white Moore Light produces a spectrum which accurately duplicates this spectrum of average daylight and there has never been an instance where the color values of the white Moore Light have not given absolute and entire satisfaction. In fact, nothing further in the way of improvements in the color values of the Moore Light can be conceived. I have not yet been able to discover any large dyeing establishment or other industry dependent upon color values which operates all night except by use of the white Moore Light.   Yours truly,

                    (Signed)   D. McFarlan Moore.

The Oxy-Acetylene Flame. Anon. (*Eng. Record,* lxii, 12.)— Although this flame has been found exceedingly useful for the removal of wrecked steel in many cases, yet it appears that the fears entertained that burglars might use it for attacking safes have proved practically groundless. In one case where the flame was used on a safe put in place in 1883, before oxy-acetylene was applied to such purposes, the damage done was merely of a superficial character. Modern safes are insulated with materials which resist penetration. The substance most commonly used for this insulation is a patented mixture containing Portland cement and carborundum, and, although the oxy-acetylene flame can be made to fuse cement alone, it is not sufficiently powerful to penetrate the combination of the two materials mentioned. The necessity of the case led to the invention of a flame-proof insulator.

HONORS BY THE FRANKLIN INSTITUTE.

No title of nobility may be granted by the United States, according to the Constitution; but there is no law which can prevent the reward of just merit. There are various societies and institutions in this country from the Cincinnati to the Hall of Fame which confer more or less distinction upon persons living or dead. Some of these honors are for merit and some by reason of primogeniture. There are all sorts of academies, too, which confer more or less distinction by virtue of membership. But the real aristocracy of this country, so far as achievement for the substantial benefit of mankind is concerned, includes especially those who have been honored by the Franklin Institute of this city.

The Institute confers various medals, according to their foundation, upon men who have accomplished much. Scarcely anywhere is there a more meritorious recognition than goes to the man who wears a Cresson gold medal. No one has this " order " without having won it by notable achievements through which mankind has been benefited. The Nobel prizes are richer in emolument, but fundamentally not so distinctive. The Franklin Institute looks less to ethics than to achievement. Nor is it insular. Of the seven medals just granted, three go to foreigners and only two to Pennsylvanians. Nearly every one of these men is past the greatest period of activity, so that the medals come as rewards for service rather than as incentives.

Of the many institutions which bear Franklin's name none has accomplished more in the past eighty-five years than the Franklin Institute. Indeed, there is not a single American society of that kind which stands so high throughout the world. It is, therefore, humiliating that the Institute should be housed in such poor fashion, that its efforts to get new quarters should have so far come to naught and that its assets are so meagre. The stimulus and the instruction given by this institute have made, directly or indirectly, many American millionaires, and it is much to be regretted that these have not endowed the Institute sufficiently to establish it in fine modern headquarters and to provide a fund for increasing its activities, which are always solely for the practical uplift of society.— Editorial, *Evening Bulletin,* Philadelphia, December 6, 1910.

CURRENT TOPICS.

Decomposition and Weathering Phenomena in Young Volcanic Rocks. C. GAGEL. (*Centr. Min.*, 1910, 225.)—Through chemical analysis of trachydolerites and phonolites from Madeira and Teneriffe, and their decomposition products, the progress of kaolinization in the rocks is shown. This kaolinization is ascribed to the action of carbon dioxide. Other varieties of decomposition in Teneriffe in which no kaolin was formed are ascribed to contact action, or regional influences. Certain feldspar residues are assumed to be of a colloidal nature.

To Preserve Rubber Tubing. (*Pharmac. Journal*—from *Amer. Mach.*, xxxiii, 34.)—Immerse the rubber tubing in a mixture of 1 part ammonia and 2 parts water for a time varying from a few minutes to half an hour or an hour, until the original elasticity is regained; or frequently wash the articles in slightly alkaline water. Keeping the goods in air-tight vessels will preserve them for a long time; and so will well closed tin boxes containing quicklime and ammonium carbonate.

The Composition of Gas in Very Hot Flames. (*La Nature,* No. 1948, 129.)—The products of combustion of gases in very hot flames are not always identical with those generally met with. Thus it has been shown that in the presence of an excess of oxygen the combustion of carbon monoxide gives ozone; under the same conditions the hydrogen flame also contains ozone and a little nitrous oxide; and further the acetylene flame contains almost 4 per cent. of this same nitrous oxide. The temperatures attained during the combustion of these gases, under the above conditions, are exceedingly high, about 2600° C. for carbon monoxide, 2800° C. for hydrogen, and 3000° C. for acetylene.

Aluminum-Bronze. E. S. SPERRY. (*Brass World,* vi, 3.)— Aluminum alloys with copper in all proportions and produces homogeneous mixtures. When the aluminum goes beyond 10 per cent. the bronze gets brittle, and a 12 per cent. mixture is hard enough for hard dies. For sand casting the 10 per cent. alloy is generally used, as it is hard and tough and has the properties of a strong metal. The great difficulty in casting aluminum-bronze is its oxidation when melted. It must be poured without agitation, to avoid dross. Dross formed in melting may be skimmed off, but that which is formed while pouring enters the casting. Another difficulty is the shrinkage. By the use of sufficiently large risers, and the avoidance of sharp corners in the casting, and an ample

gate, this shrinkage may be overcome. The toughness of aluminum-bronze is greater than that of any metal except steel. It works hot better than copper, as it is softer at a red heat, and it is not black-short like copper and zinc alloys.

The Spectrum of Radium Emanation. H. E. WATSON. (*Proc. Roy. Soc. London,* A., lxxxiii, 50.)—Royds, in a criticism of Cameron and Ramsay's spectrum, stated that this included Xe lines, on which account this research was undertaken. The gas was purified by Ramsay, being sparked in the presence of fused KOH, frozen in liquid air, and the excess of hydrogen pumped off. Photographs were taken with a prism spectrograph and with a grating, and compared with a Xe spark spectrum. The author concludes that ten of Collie and Ramsay's lines were due to the emanation, and the remainder were mercury lines. The identity of Xe lines in Cameron and Ramsay's spectrum is undoubted, but could not be due to accidental contamination, as Royds suggested. No Xe ever entered Ramsay's private laboratory, and contamination by air would have introduced Kr lines also. Apparently the emanation has broken down into Xe, possibly Cu acted as the transforming agent.

To Restore Their Phosphorescent Properties to Alkaline Earth Sulphides. D. GERNEZ. (*Ann. chim. phys.,* xx, 166.)—The sulphides of barium, strontium, and calcium lose their phosphorescent properties after long exposure. Exposure to light, darkness, heat, or moisture has but little restorative effect, but when a current of dry hydrogen is passed over them, they phosphoresce as brilliantly as when first made. While hydrogen is reacting, water vapor is set free accompanied by a series of small explosions.

The Volatile Matter of Coal.—The first bulletin to be issued by the new Federal Bureau of Mines will bear the above title. The authors, Horace C. Potter and F. K. Ovitz, conducted their investigations at the Pittsburg station while it was under the Technologic Branch of the Geological Survey, the work being a continuation of the fuel investigations begun several years ago at the Louisiana Purchase Exposition, St. Louis, Mo. The results obtained at that plant showed that the work of determining the fuel values of the coals and lignites in the United States with a view to increasing efficiency in their utilization would be incomplete if it did not include systematic physical and chemical researches into the processes of combustion. Hence in their later investigations the authors carried on such researches, concentrating attention on those lines of inquiry which promised results of greatest economic importance. This bulletin is therefore a report on an investigation of the volatile matter in several typical coals—its composition and amount at different temperatures of volatilization.

Quoted directly the authors say: " The investigation has already

shown that the volatile content of different coals differs greatly in character. The volatile matter of the younger coals found in the West includes a large proportion of carbon dioxide, carbon monoxide, and water, and a correspondingly small proportion of hydrocarbons and tarry vapors. The older bituminous coals of the Appalachian region yield volatile matter containing large amounts of tarry vapors and hydrocarbons, difficult to burn completely without considerable excess of air and a high temperature. Coal of the Western type, moreover, gives up its volatile matter more easily at moderate and low temperatures than that of the other type. The volatile matter produced at medium and low temperatures is rich in higher hydrocarbons of the methane type, such as ethane and propane, which contain a larger portion of carbon than is present in methane.

" These facts help to explain the difficulty of burning Pittsburg coal, for example, without smoke, the low efficiency usually obtained in burning high-volatile Western coals, the advantage of a pre-heated auxiliary air supply introduced over a fuel bed, and the advantage of a furnace and boiler setting adapted to the type of fuel used. They bear directly also on the question of steaming ' capacity ' of coal for locomotives, the designing and operation of gas producers for high-volatile fuels, and the operation of coke ovens and gas retorts.

" The results show further that certain bituminous coals of the interior and Rocky Mountain provinces give promise of good yields of by-products of coking, notably ammonia and high candlepower gas, comparing favorably in these respects with the high-grade coking coals of the eastern province.

" They show also that inert, noncombustible material is present in the volatile products of different kinds of coal to an extent ranging from 1 to 15 per cent. of the coal."

The publication will be of interest to fuel engineers, designers and builders of gas producers, gas and coke manufacturers, super-intendents of power plants, railway master mechanics and those engaged in the suppression of smoke. Copies of the bulletin may be obtained by applying to the Director of the Bureau of Mines, Washington, D. C.

Department of Non-ferrous Metallurgy. (*Times, Eng. Suppl.,* Oct. 26, 1910.)—Prof. J. O. Arnold in his presidential address to the Electrometallurgical Society of Sheffield, England, stated that the University contemplated the establishment of a department for the study of non-ferrous metals. The University authorities had already provided a Kjellin non-ferrous crucible, with the aid of which a series of tests would be made as to the relative merits of coke and electric melting of base metal. The University was already in a position to experiment on the electric melting of brasses, bronzes and German silver.

Positive Band Spectrum of Nitrogen. E. ANGERER. (*Ann. de Phys.*, xxxii, 3.)—A complete article on the positive band spectrum of nitrogen and the changes it undergoes with decrease in temperature. Various forms of vacuum tubes were employed both with and without electrodes, and great care was used to prepare a pure nitrogen. The changes which occur are given in detail, and the wave-lengths of the lines.

Helium in the Atmosphere. A. PIUTTI. (*Le Radium*, vii, 142.) —The author describes a sensitive method of estimating the amount of helium in the atmosphere and in minerals. The principle depends upon the absorption of the gases other than helium by cocoanut charcoal immersed in liquid air. The helium is estimated by the intensity of the various helium lines in a spectroscope placed along the prolongation of a Plucker tube. He succeeded in tracing the presence of helium in 3.5 c.c. of air at Naples. He also gives measurements of helium given off when different Zircons are heated, and compares these measurements with their radio-activity and density, of nineteen Zircons examined; that from Vesuvius contained the least helium relative to its radio-activity, and that from Renfrew (Canada) the most.

Portability of the Weston Cell. H. TINSLEY. (*Electrician*, lxv, 568.)—To prevent the ingredients of a cell being displaced in transit, drum-heads of cork and linen are placed over the solid chemicals. Cells set up in this way do not appear to have their e.m.f. affected by this linen screen, and as this becomes at once impregnated with solution, its resistance is kept low. These cells appear to have a very uniform resistance of about 700 ohms.

Chemical Reactions and Ionizations. M. G. REBOUL. (*Mon. scientifique*, xxiv, 826.)—Alkaline metals, which oxidize in damp air, emit charges of both signs, with negative charges preponderating. If two perfectly insulated vessels, one containing ammonia and the other hydrochloric acid, are placed between the armatures of a condenser in such a way that the field becomes active at the moment of reaction, when ammoniam chloride is formed, a current passes between the two armatures. When nitrogen di-oxide reacts with oxygen in a platinum apparatus, the charges disappear almost entirely, they reappear if damp copper is introduced into the apparatus; these charges proceed from an action on the electrodes.

On the Relative Duration of Calcium Rays in the Spark of Self-induction. M. G. A. HEMSALECH. (*Comptes rendus*, cli, 220.)—In the consideration of arc rays it is noticed, as has been previously observed of the rays of iron, that their duration is nearly proportional to their intensity. The duration of the spark

rays shows a more rapid abatement of the atomic vibrations to which they are due, than the arc rays. Even the most intense rays, H and K, do not last as long as some weaker arc rays. The ray 3706, with an intensity of 10, has the shortest duration of all the rays. The examination of calcium, containing traces of Sr, Mg, Al, and Mn, gives these results: Always distinguishing between arc rays and spark rays, and granting that the duration of a ray depends on its intensity, the duration of strontium rays is far greater than that of calcium rays. On the other hand, the rays of magnesium are relatively shorter than the corresponding rays of calcium. The two aluminum rays between H and K have almost normal duration, while the triple rays of manganese show a greater duration than the equally intense calcium rays. It follows from these data that the observation of the relative duration of spectral rays might, in certain conditions, give useful indications in the analysis of substances containing unknown impurities.

Removal of Paraffin, Vaseline, etc. C. BENEDICKS. (*Phys. Zeitschr.*, xi, 254.)—Paraffin and vaseline, etc., can be removed by washing with condensing alcohol vapor. Thus by inserting a beaker which has contained paraffin over another containing a little alcohol and placed on a water bath, the paraffin is removed. This method can be applied to the removal of grease from the fractured surface of steel, or from articles to be silvered and so on.

A Carthaginian Lamp. M. EUGÈNE COLLIN. (*Mon. scientifique*, xxiv, 826.)—The microscopical examination of the wick fibres, after bleaching with permanganate in sulphuric solution and then treating with bisulphite, shows that this wick consists of flax fibre.

Composition of Greek Vases. W. FOSTER. (*J. Amer. Chem. Soc.*, xxxii, 1259.)—Experiments show that the black glaze of the Attic styles of vase is due to ferrous iron probably as silicate, while the red glaze of the Mycenaean style is probably due to ferric iron. These views are supported by synthetic experiments. The complete analyses of fragments of vases show that the Mycenaean pottery is much poorer in silica and richer in lime, and therefore more fusible than the Attic.

Metallic Strontium. B. L. GLASCOCK. (*J. Amer. Chem. Soc.*, xxxii, 1222.)—This metal was obtained by fusing pure strontium chloride in a hemispherical iron cathode vessel 25 cm. in diameter, with walls 0.6 cm. thick, with a carbon anode 8 cm. x 8 cm. This allowed a low anode current density and avoided overheating. With a current of 125 ampères and 40 volts for 7 hours, 76 Gm. of metal were removed in small lumps up to 3 Gm. in weight. The

metal is removed from the mixture by crushing on an iron plate and then sifting away the chloride. Analysis showed it to contain about 98 per cent. of metallic strontium, which is a light metal, with a silvery lustre when cut, gradually becoming yellow and finally white and non-lustrous. It is softer than calcium and can be cut with a knife. It alloys with iron. Hydrogen and nitrogen unite with the heated metal. The specific gravity is 2.55 and the specific heat 0.0742, corresponding to an atomic heat of 6.5. The iron alloy is rather hard, and decomposes water. This alloy contained 23 per cent. of strontium.

Radiation Pyrometers.—The Cambridge Scientific Instrument Co., Ltd., has patented a radiation perometer which consists of a closed tube, in one end of which a sensitive element is arranged with a mirror, lens or diaphragm so that the radiation from the other end, which is exposed to the temperature to be measured, may be recorded. Focussing is thus avoided, and since true " black body " conditions are established the readings are independent of the nature of the surface of the hot end of the tube.

Power Gas and its Development. J. S. S. BRAME. (*Chem. Trade J.,* xlvii, 376.)—The introduction of power gas has made considerable economy possible in the use of fuel resources. Blast-furnace and coke-oven gas, previously wasted, can be utilized and the replacement of steam power by gas power would diminish the annual consumption of coal for power by 9 million tons, or 20 per cent., in England. Power gas can be generated from heat or other poor fuels not suitable for raising steam. There are 140 million acres of peat bog in Europe. For small powers up to 30 h.p. he recommends the use of coal gas rather than a gas plant ; from 30 to 250 h.p. a suction gas plant is recommended; and for greater power, a pressure gas plant. Recent developments are the use of the engine exhaust in place of steam in the producer, and the abolition of the gas holder in pressure gas plants, the production being controlled by fans driven by the engine.

Value of Waste Yeast. G. GRAF. (*Allgem. Zeit. Bierbrau,* xxxviii, 372.)—Waste brewery yeast is but little utilized and great quantities of potentially valuable food material are annually wasted. Yeast has been proved to be a suitable addition to cattle food when supplied in quantities of 1 pound per 100 pounds of live weight. Cakes of compressed yeast and spent hops are readily eaten by cattle and should provide a cheap and generally used food-stuff. Such food could be prepared at a far from prohibitive cost. The waste yeast is first washed, drained and pressed to remove the excess of moisture ; it is then plasmolysed by adding 1 to 2 per cent. of common salt and dried. The compressed cakes

of yeast and spent hops have the following composition: water 10, proteins 55, non-nitrogenous extractives and cellulose 24.2, ash 7.8, and fat 3 per cent. They should be worth three dollars per hundred weight.

Waterproofing Filter Beds and Reservoirs. (*Eng. Record,* lxii, 16.)—Mr. H. Ashley, Engineer of the Portsmouth (England) Water Co.'s plant at Farlington, reports that an area of seven acres of floors and walls of the filter beds and reservoirs were waterproofed by two coats of cement plastering. The first coat was three-quarters of an inch thick and the second one-quarter of an inch. The result was very successful, as careful tests frequently repeated, disclosed no leakage whatever.

Solubility of Finely Divided Gold in Potassium Ferrocyanide Solution. E. BEUTEL. (*Monats. Chemie,* xxxi, 887.)—Finely divided gold dissolves slowly in potassium ferrocyanide solution at the ordinary temperature, and forms a distinctly alkaline solution; solution is very slow even at boiling point. Apparently potassium aurocyanide is first formed, and the liberated ferrous ions are oxidized by the atmosphere to ferric hydroxide, which is precipitated, in amount corresponding to the amount of gold dissolved. Prolonged action of a strong solution of potassium ferrocyanide seems to give ultimately potassium auricyanide.

Problems in Soil Fertility. J. G. LIPMAN. (*J. Agric. Sci.,* iii, 297.)—By growing oats in the inner, and peas in the outer of two concentric pots, the inner pot being very porous in one case and glazed in the other. The beneficial effect of the legume on the growth of the grain was clearly shown when the inner pot was porous. As no nitrogen was supplied, it was evident that soluble nitrogen compounds were passing from the peas to the oats through the unglazed inner pot. This device might be applied to the study of other problems as to the action of one crop on the growth of another.

Impermeability of Gelatin Increased. A. and L. LUMIÈRE and A. SEYEWETZ. (*Photo. Jour.,* l, 34.)—From experiments it is concluded that substances which render gelatin insoluble, also decrease its permeability, measured by the amount of water absorbed in a given time. The substances used are placed in the order of their power of decreasing permeability; formalin, sodium-quinonesulphonate, quinone, chrome-alum, potassium-alum. The last is not a true insolubilizing agent as it only raises the melting point of gelatin, and is weaker in its action than the other four. Sodium-quinonesulphonate and quinone, although they stain the gelatin and are not so powerful as formalin, are preferable in photography,

since the contraction induced by formalin separates the gelatin from the glass. Much more quinone and sodium-quinonesulphonate can be used than formalin without decreasing the fluidity of the resulting gelatin solutions.

Uranium Ore in Mexico. (*L'Ind. Chimica,* x, 270.)—Mr. W. Niven discovered a new mineral in the Guerrero district of Mexico which was a hydrophosphate of uranium and copper. This mineral, which is called torbernite has a slight action on a photographic plate in the dark. Experiments are being made to ascertain the suitability of the mineral as a raw material for the manufacture of radium salts.

Recent Hydro-electric Practice in Switzerland. PROF. W. F. DURAND. (*Eng. Record,* lxii, 20.)—A very interesting illustrated article on hydro-electric power plants in different parts of Switzerland which will amply repay perusal.

Transference of Heat. W. MUSSELT. (*Eng. Record,* lxii, 20.) —Mr. Mussell states that heat transfer through the walls of a pipe at any point is independent of the velocity, density, and specific heat of the fluid in the pipe, but is directly proportional to the coefficient of heat conduction and inversely proportional to the diameter of the pipe.

Metallic Coatings. (*Eng. Record,* lxii, 20.)—Mr. M. U. Schoop has produced metallic coatings on cloth, paper, wood, and metal by a spraying process. The fused metal is discharged through a fine orifice and turned into a fine spray by a current of air or gas blown across the jet at a high pressure at a right angle. The minute particles of metal are so cooled by the air or gas jet that they do not ignite the coated material.

Silica Discovered in Canada. (*Oil, Paint and Drug Reporter,* Oct. 3, 1910.)—An apparently unlimited quantity of silica, free from iron, has been found at St. Anne's, Manitoba. It was at a depth of 194 feet and was driven through for 14 feet without finding the bottom of the deposit. A similar discovery was made on a neighboring farm.

Pyrophoric Alloys and the Modern " Flint and Steel." (*La Nature,* No. 1952.)—These " flint and steels," like those of our forefathers, produce sparks by the blow of a piece of steel on a special stone. But this stone is not the old flint of long ago, and the sparks are so hot that at the first blow they will kindle tinder or a match soaked in benzine or alcohol.

This discovery is due to Auer, who found the necessary qualities

in an alloy of iron and cerium. It has been known for some time that other metals than iron would give pyrophoric sparks when struck. M. Chesneau, in 1896, showed that uranium gave sparks that would kindle a mixture of inflammable gases. The pyrophoric qualities of the cerium family of metals have long been known. But alone they are too soft and light, and Auer conceived the idea of alloying them with iron.

Electric Steel Refining. (*Eng. Record,* lxii, 20.)—The U. S. Steel Corporation has been paying attention to a number of methods of increasing the quality of some of its products, and to this end has acquired complete control of the Héroult patents in America. The electric refining experiments at South Chicago, on steel produced in a Bessemer converter, were intended to improve metal for rails and axles, and thus compete with the wholly different Gayley methods. These improvements, due to Mr. W. R. Walker, are said to have decreased the cost of the process. Enough has been said to justify a belief that real progress has been made in the art of producing better steel in large quantities at reasonable prices.

Guages Used in Testing Materials. H. F. MOORE. (*Amer. Mach.,* xxxiii, 44.)—A valuable description of guages used at the University of Illinois for testing small strains over various parts of the specimen under test. Ames dial guages are used to test large specimens. These tests include those for tension, compression, deflection and fibre strain on wood, steel, concrete, and terra cotta. An ingenious method of calibrating the guages is described.

The Unstable Equilibrium of the Balloon. TECUMSEH SWIFT. (*Amer. Mach.,* xxxiii, 44.)—An interesting article, endeavoring to point out out how little is really known of the necessities of aviation, and how much is left to chance and "rule of thumb" work. "The dirigible balloon is entirely a balloon and only slightly a 'dirigible.' It must wait upon the fickle winds and can not oppose them."

Powder Thawing Device. (*Eng. Record,* lxii, 17.—From the *Mining and Scientific Press.*)—This is constructed by boring two 1¼ in. holes in the side of a barrel, 6 in. from each end, in the same vertical line, fitting a 4 or 5 ft. length of pipe into each of these holes and connecting the outer ends of the pipes with another length. A grating or rack is fixed in the barrel, on which a 5 gallon oil can is placed containing the powder to be thawed. The open top of the can is just below the upper rim of the barrel. The barrel is filled with water to just above the upper pipe level and a fire lighted beneath the lower pipe near where the vertical riser connects it with the upper horizontal pipe, so that the heated water

circulates. The powder in the can is said to thaw gradually and safely. The barrel and can are fitted with separate covers. The can should be cleaned after each operation, to remove any traces of exuded nitroglycerin.

Preparation of Hydrogen by Silicium. (*La Nature*, No. 1952.) —The development of aeronautics, especially from the military point of view, has made the manufacture of hydrogen of great importance. A German society, the Consortium of electrochemical industry of Nuremburg, has patented a process which appears to give excellent results. By this process a solution of sodium hydroxide, mixed with a little calcium oxide (lime) is decomposed by silicium prepared in an electric furnace. The gas thus obtained is very pure; 2.2 kg. of silicium produces a cubic metre of gas.

Ventilating Tunnels and other Workings by Water Power. (*Eng. Record*, lxii, 15.)—Taken from " Mining and Scientific Press." This method consists of allowing a stream of water to fall through a vertical passage whose lower terminal is in a closed chamber and beneath a constant water level. The water escapes through a submerged orifice as fast as it enters, and the air carried down by the stream accumulates in the space above the water level, developing the pressure which forces it through mains to the desired point. The upper end of the vertical passage is covered with a screen so as to break up the entering stream. A fall through a 12 in. pipe, 30 ft. long, is said to have provided an abundant supply at a distance of 600 ft. from the air chamber.

Copper Sulphate to Prevent Algæ. (*Eng. Record*, lxii, 15.)— Four of the reservoirs of the Albany water works were treated with copper sulphate before the warm weather. Two were treated four times during the season, one three times, and the other twice. The maximum amount used during any one operation was 0.32 parts per million and the minimum quantity 0.1 parts per million. Mr. H. J. Deutschbein, Superintendent of the water bureau, accounts for the fact that no complaints regarding algæ were received during the year, to the early start of this treatment and the constant watching of the aquatic growths. The reservoirs are supplied with filtered water from the Hudson River.

Some Common Defects in Alloys. C. H. DESCH. (*Inst. of Metals*, Sept., 1910.)—The common defects of non-ferrous alloys are here classified, and the causes and means of detecting them are discussed, and the conditions under which they occur. The defects are (1) sponginess, due to the enclosure of gas; (2) brittleness or weakness, due to the presence of oxides or other drossy matter, or intercrystalline metal or eutectic alloy; (3) defects due to inequalities of composition, caused by imperfect

mixing of the ingredients, separation by gravity during solidification, or segregation in the mould; (4) excessively coarse structure, due to casting at too high a temperature; (5) defects due to wrong thermal treatment, such as quenching from a high temperature, heating at too high a temperature or for too long a time during annealing, " burning " in the case of alloys of copper and zinc, or unequal thermal treatment of different parts of the same casting or forging; (6) defects due to molecular change other than that produced by mechanical stress; (7) shrinkage cracks; (8) defects due to molecular change produced by mechanical deformation, viz., brittleness of cold-worked metals, chilling cracks, and cracking during hot working; (9) corrosion; (10) erosion.

Gas Evolution and Capacity of the Lead Accumulator. F. STREINTZ. (*Zeit. Elektrochem.*, xvi, 747.)—A complete investigation of the gas evolution (compared with a copper voltameter) and of the changes in potential of the electrodes in an accumulator lends to the conclusion that hydrogen may be occluded by the reduced negative plate in charging. Oxygen absorption also takes place in the positive plate, but this is due to its penetration to the metal and formation of more peroxide. The discharge data show that the sharp fall in potential may be due to the exhaustion of the negative or of the positive plate. The former is the more usual case in actual practice, but the latter may occur either (1) in an initial discharge when the positive plate is not completely formed; or (2) when the charging has been so carried out that the negative plate has been enabled to occlude considerable quantities of hydrogen. In the latter of these cases the capacity of the cell is of course found to be higher than usual.

Sparking at the Electrodes. A. KAILAN. (*Zeit. anorg. Chemie.*, lxviii, 141.)—The anodic disturbances which are observed occasionally in the electrolysis of fused lithium chloride and other salts have been investigated. The author does not support the view that the phenomenon is caused by the formation of a sub-chloride in the melt, or by the appearance of a film of silicic acid (from the vessel) on the cathode. The electrolysis proceeds normally with a higher temperature and he suggests that the cause is a change in the viscosity of the melt. This view is supported by the fact that under similar conditions the critical temperature is 100° higher for pure lithium chloride than for a 50 per cent. mixture of lithium and potassium chlorides. The sparking is produced quite readily with a platinum (instead of a carbon) anode, while there is no disturbance at all with an alternating current. While the sparking lasts it is noticed that the apparent resistance of the cell decreases with increasing e.m.f. A mixture of 1 part lithium bromide with 6 parts lithium chloride does not spark nearly so

easily as pure chloride nor as a mixture of lithium and potassium chlorides. Oscillographic reproduction of the curve of current strength during the disturbance shows that when the anode is sufficiently deeply immersed, there are no great fluctuations with an e.m.f. of 110 volts and a resistance of 19 ohms. From these facts the author prefers a purely physical explanation of the phenomenon.

Cold Vulcanization. H. E. POTTS. (*Zeit. chem. Ind. Koll.,* vii, 111.)—Bysow's explanation of the adsorption of sulphur-chloride by rubber is insufficient. Bysow measured the surface tension air-solution. The determining factor in adsorption on Gibbs' theory, is the variation in the tension rubber solution. This latter is unknown. In an editorial note W. Ostwald agrees, but suggests the two tensions may run in parallel series. He notes that Traube's theory of attraction pressures is open to the same objection.

Electric Steel Refining. D. F. CAMPBELL. (*Iron and Steel Inst.,* Sept., 1910.)—Describes the great possibilities of electrical refining in conjunction with the various steel processes. The increase in the capacity of the Talbot and other open-hearth furnaces is very important, because the expensive processes of desulphurization and attaining a teeming heat can be most profitably carried out by transferring a portion of the charge to the electric furnace and making up again in the main furnace with raw material. It will be cheaper to add an electric furnace to a Bessemer plant than to replace it by open-hearth furnaces. The following are the most desirable features of design: 1. The best open-hearth design, with homogeneous solid bottom and bands free from imbedded electrodes. 2. All electrical mechanism, generators, transformers, etc., should be separate from the furnace. 3. Maintain a high power factor. 4. The roof should be protected from direct radiation by the electrodes and the intensely heated area of slag should be as large as possible. 5. The heat should be applied to the slag, which must be kept very fluid and hotter than the steel.

The Quality of Boiler Tubes. (*Iron Age,* lxxxvi, 16.)—At the Convention of the American Boiler Manufacturers' Association, Mr. Charles S. Blake, Secretary of the Hartford Steam Boiler Inspection and Insurance Co., attacked the quality of boiler tubes. He stated that " tube failures are woefully common. Twenty-five years ago the average steam pressure ran from 80 to 100 lbs., and the tubes in use at that time were identical in thickness, except in specific instances, with those in use to-day for pressures of 150 lbs. to 175 lbs., and the average quality has not improved, so that the standard commercial tube of to-day is no better than, if as good, as the tube of those days."

Mr. Blake's assertions are evidently based upon the findings of the company's inspectors. If these reports are made without thorough investigation, the manufacturers of boiler-tubes are being grievously wronged. If the facts are as stated, the tube manufacturers should take steps to bring the quality of their product up to the requirement of the times.

Mordant Dyestuffs. E. NOELTING. (*Chem. Zeit.*, xxxiv, 977.) —The author states that when a dyestuff, particularly one belonging to the anthroquinone series, contains a hydroxyl and an amino-group in the ortho-position with respect to one another, the substance has mordant dyeing properties. Mordant dyestuffs are sometimes formed when the two groups are in the para-position respectively, but the affinity for the fibre is not so great in this case. It is remarkable that all amino-hydroxy-compounds give strong colors on a copper mordant.

Grahamite, a Solid Native Bitumen. C. RICHARDSON. (*J. Amer. Chem. Soc.*, xxxii, 1032.)—Grahamite was discovered in West Virginia, in about 1860, but there is considerable confusion in literature as to its distinction from albertite and gilsonite and to a certain extent from manjak. It may be described as a brittle, solid native bitumen, generally pure, but at times mixed with adventitious mineral matter; characterized when pure by a peculiar schistose fracture, known as "hackly." It does not melt, but intumesces; it is soluble in carbon bisulphide and to a small extent in light naphtha and yields a high percentage of coke. It closely resembles the "asphaltenes."

European and American Wood-block Pavements. CLIFFORD RICHARDSON. (*Eng. Record,* lxii, 14.)—This interesting communication compares wood block pavements as laid down in Paris, London and New York. The weak points of the American system of constructing wood-block pavements are,—lack of depth to the block, extravagance in the matter of saturation, neglect to use a waterproof filler, and the use of a mortar bed instead of a smooth-floated concrete foundation.

Asbestos in the United States.—The United States has for years led all other countries in the manufacture of asbestos goods, but until recently all the raw asbestos used has been imported from Canada, where there are nineteen quarries and mills, having a capacity of 8250 tons of rock a day and employing in summer more than 3000 persons.

A feature of the asbestos industry of 1909 was a combination of Canadian producers in the Amalgamated Asbestos Corporation (Ltd.) and the formation of the International Asbestos Association,

an organization including mine owners in Canada and manufacturers in the United States.

No asbestos of the higher grade (serpentine asbestos, or chrysotile) was mined in the United States until 1908, but in that year Vermont produced some chrysotile and in 1909 mined a larger quantity, amounting to nearly one-twentieth of the Canadian output. Chrysotile asbestos has been mined in small quantities in Wyoming during the present year.

Asbestos is insoluble in acids and incombustible, is a poor conductor of heat and electricity, and is not affected by dampness, so that it is applied to many purposes. It is used for building material, pipe coverings, shingles, insulating tapes and boards, fireproof ropes and curtains, packing for fireproof safes, and packing for steam engines, as well as in paint and cement.

The United States Geological Survey has just published a report on the production of asbestos in 1909, by J. S. Diller, showing the production, imports, prices, and trade conditions during the year as well as the foreign production and trade conditions. The report contains also notes on the known asbestos deposits of the United States.

In 1909 the production of asbestos in Vermont was 200 per cent. and that of Georgia about 25 per cent. more than in 1908. Mr. Diller urges that the search for chrysotile asbestos be continued among the ancient crystalline metamorphic rocks in the United States.

Electric Arc Welding. F. SCOTT ANDERSON. (*Amer. Mach.,* xxxiii, 40.)—This article is important to those requiring such welding. It points out the advances made, particularly in portable plants. It gives a series of tests comparing the efficiency of such welds with hand welds made at a forge and with the original metal. It points out the kind of electrodes necessary, the precautions to prevent burns, and that the low tension is a safeguard from shocks.

A Fourth Recalescence in Steel. PROF. J. O. ARNOLD. (*Iron Age,* lxxxvi, 16.)—From the accumulated thermal and micrographic observations of more than 20 years, the view is put forward that the fourth phase of recalescence is due to the heat evolved during the segregation of the ultimate micrographic constituents of steel, begun at Ar_3 and completed at Ar_1, during the cooling of an unsaturated steel at a moderate rate. Between the points named it is believed the Ferrite and Hardenite fall out from their state of solid solution into microscopically visible masses.

North Dakota Lignite as a Fuel for Power-plant Boilers is the title of Bulletin No. 2 recently issued by the Bureau of Mines. This bulletin describes a series of tests at the pumping plant of the United States Reclamation Service at Williston, North Dakota.

The Reclamation Service has a large project there and had installed steam boilers with furnaces designed to burn a "brown lignite" that was mined on adjacent Government land.

The furnace is of the semi-gas-producer type and has an external resemblance to the so-called Dutch oven. The most striking features in its construction are the deep-set grate and the construction of the space between the bridge wall and the end of the prolonged fire brick arch. The furnace is designed to work on the gas-producer principle. The solid fuel is gasified on the grate and the gas passes through the space under the arch into the combustion chamber where most of the gaseous combustible burns.

The results of the tests on the lignite show that this fuel, though generally considered unsatisfactory, may be used with fair economy under boilers that generate their full rated capacity. In fact, when the number of heat units available is considered, the results compare favorably with those of better grades of fuel.

The tests are deemed important because the lignite deposits of the Northwest are so extensive and the distance of the region from other coal fields is so great that a large portion of the United States, including parts of North Dakota, South Dakota and Montana, may be greatly benefited by any improvements in the methods of utilizing this local fuel supply. The lignite in this field is low in heating value, some of it containing nearly 45 per cent. of its weight in moisture, and it is difficult to burn in the furnaces commonly used for the better grades of coal, but the tests have shown the possibility of designing suitable furnaces for burning it profitably.

The tests were conducted by the Technologic Branch of the Geological Survey which is now a part of the Bureau of Mines.

The Compass for Hardening Heats. GEORGE COLES. (*Amer. Mach.*, xxxiii, 39.)—It is stated that the proper heat for hardening carbon steel is indicated by its loss of magnetism, so that if a tool be suspended in the furnace from a magnet, it will drop at the critical moment that it reaches the correct heat for hardening. Mr. Coles says he can replace the magnet by a compass, and as soon as the magnetism in the tool ceases to affect the compass, the proper temperature is attained. The higher the content of carbon in the steel, the lower the temperature at which it will harden.

SIMPLICITY IN THE MEASURES OF PHYSICAL QUANTITIES.

BY

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COMPLAINT is frequently heard against the time robbing and inconsistent system of units of measurement which we have been so unfortunate as to inherit from our forefathers, yet in thus complaining about what our forefathers handed down to us, are we doing our best now to correct this state of affairs and not to pass on to our successors irrational, inconsistent, unnecessary, ill chosen and even incorrect units of measurement which are still under our control and are not yet so universally established and so deep rooted as the foot, pound, gallon, horsepower, etc.?

In the writer's opinion we are not doing all that can and should be done in this rapidly developing science of measures, with a view to the simplification of our every-day calculations and the rationalization of our systems of units of measurement. We are to-day doing things which are likely to take deep root and which our descendants would have quite as good a right to complain of as we have in complaining about the wretched system which has been handed down to us so firmly rooted that it will require generations to eradicate it.

The purpose of the present article is to point out what might be called the ideal system, from the stand-point of simplicity of calculations and clearness of conception, thereby showing the

existing inconsistencies and mistakes, some of which it is well within our power to correct, but which if not checked will take deep root. It is not the intention to enlarge here upon the merits of the much discussed metric or the duodecimal systems. The universal adoption of the former is only a matter of time, although probably it will require a generation or two, and the adoption of the latter is beyond our hopes and will probably be done first by those nations like Japan and China, which are younger in this branch of civilization and can therefore adopt radically new departures with less mental inertia.

In order to see whether we are to-day doing anything which might just as well be done better and is capable of being changed, let us first examine what might be called the theory of systems of units.

Measures are intended for designating definite amounts of something. With but few exceptions these things are all physical quantities, like length, weight, time, velocity, angles, electricity, light, heat, power, etc. These physical quantities are all given to us by nature and are not creations of man; we therefore have no choice but to accept them as we find them. But in no case does nature give us any units in terms of which these quantities are to be measured; these units are always the creation of man and are therefore within our power to designate. In some cases nature has indicated to us a rational unit, as for instance the period of the revolution of the earth, on which we have based our indestructible and reproducable unit of time; but with few exceptions, the many units that we have are entirely artificial creations, although a creditable but futile attempt was made to base the metric system on a natural basis.

To measure a physical quantity, it is necessary to propose, define and adopt some one fixed amount of it, which is to be considered as the unit of that quantity; without some form of unit it is evidently not possible to express or measure an amount of that thing. Moreover, if this thing is a physical quantity which is used and measured frequently, it is very desirable to give that unit a name, like the foot, horsepower, candlepower, volt, etc. When the unit is unnamed one has a natural hesitancy to use it, and it then becomes necessary to carefully and clearly define it, whenever it is to be used to measure a quantity; and if in such a case a physicist omits to state the units in terms of

which the quantities in his laboriously deduced and valuable physical relations and formulas are expressed (which unfortunately happens not infrequently), then his results can be used only to show relations but not numerical amounts, and they therefore lose much of their practical value.

In the ideal, most rational, and most simple system of measures and units, the first thing to do is to find out what the true nature of each of the physical quantities to be measured is, then to select some one definite amount of each, as the unit in terms of which other amounts are to be measured, and preferably to choose these units so that the relations between them will if possible be unity. This is the way it is done in that most rational of all systems, the c.g.s. system, which has been of such inestimable value to the physicist and on which our ideally simple system of electrical units is based.

This has unfortunately not always been done in the past, as for instance in the case of horsepower and watts, gallons and cubic feet, or joules, calories and foot-pounds, etc., and the result is that there exist to-day numerous cases in which there are several units for measuring the same physical quantity, where one would suffice. This not only has caused unnecessary complication and requires troublesome numerical conversion factors for reducing one to the other, but it tends also to give the impression that there is a real physical difference between the quantities measured by the different units, when as a fact they are identical.

This has been one of the chief causes of the existing complication in our systems of measures and units. In some cases, as for instance in horsepowers and watts, it was due to a natural development and was not done without good reasons; the horsepower was used as a unit long before the watt was thought of; and the watt is a necessary consequence of the simple system of electrical units. In such cases the only thing to do at present is to use the more rational one, the watt or kilowatt, more and more to the exclusion of the horsepowers, as is being done, and in course of time the irrational one will become obsolete. It is quite as simple for the mechanical engineer to multiply his foot-pounds per second by 1.356 to reduce them to watts, as it is to divide his foot-pounds per minute by 33,000 to reduce them to horsepowers.

In other cases, however, in which the irrational unit has not yet become as deeply rooted as the horsepower, the change to the more rational one could be easily accomplished by concerted action among those who have sufficient regard for the coming generations to set an example by adopting and using it. The fittest will always survive in the end, according to natures' laws, but nature can be aided in her necessarily slow methods.

A good illustration of this natural tendency to simplification, and of the mistake made in specifying and naming unnecessary units, is given by the history of the original metric system. The originators specified five units, the gramme, metre, litre, are and stere, for the physical quantities weight, length, capacity, surface, and volume respectively, when two, namely weight and length, are in fact all that are necessary. Hence the original system was unnecessarily complicated and it was no doubt in part due to this unfortunate complication that its universal adoption was not as rapid as it should have been. Had it been shown originally that all the several dozen awkwardly related units, which we inherited mostly from England, could be replaced by only two, and that these two can even be made to bear a very simple relation to each other,—the adoption of the metric units and the abandonment of our wretched system, would no doubt have been very greatly facilitated.

That some of these five metric units were unnecessary is shown best by the fact that by nature's tendency to simplification two of them, the are (surface) and the stere (volume), have nearly gone out of use already, being replaced by the metre, or its multiples. Small surfaces are to-day invariably given in square centimetres, decimetres or metres, and large ones like those in land measures, are given in square kilometres; while small volumes are given in cubic centimetres or decimetres, and large ones in cubic metres. The natural tendency to simplicity has therefore already corrected in part the mistakes made by the originators, by practically eliminating two of these unnecessary units.

The third one, the litre, is still in use, although it too is quite unnecessary, because it is a volume, and its equivalent, the cubic decimetre, would therefore suffice; this would have simplified the system, and would have avoided the present unfortunate discrepancy in the metric system in that the litre, which is legally

defined as the volume of a kilogramme of water, differs slightly from a cubic decimetre.[1]

The tendency to abandon this unnecessary litre, like the are and stere, is shown by the fact that chemists to-day usually specify volumes of liquids in cubic centimetres, and water in tanks and large reservoirs is often measured in cubic metres instead of litres. To measure wine, milk, etc., in cubic decimetres, instead of litres, would at first be opposed by prejudice and mental inertia, but it will probably not be denied that if a new system were devised to-day on the most rational basis possible, the measure of volume would be made the cube of the linear unit; this is the case in the absolute or c.g.s. system, in which no measure corresponding to the litre, exists. There is therefore nothing irrational about abandoning the litre, and sooner or later it will probably meet the same fate as the are and the stere.

This history of the metric system is, in the opinion of the writer, of great importance as a lesson to us, because it clearly points out similar errors which we are making to-day in other systems of units which are not yet so deeply rooted in practice that they could not be corrected now, thereby saving us, and the following generation, entirely unnecessary complications. Such mistakes will in the future no doubt be corrected by the natural tendency to simplicity, just as was the case with the metric system; hence there seems to be no reason why we should not enjoy the benefit of this simplicity at the present time, and also save ourselves from the inevitable censure of coming generations which would be quite as just and even more so, as our censure of the past generations for the unnecessarily complicated system which they have passed on to us.

Before specifying some of these unnecessary complications, it will facilitate matters to analyze briefly the general relationship of our measures. Omitting for the present the photometric units based on the candle, it will be found that all our units can be divided into three distinct groups, to one of which every unit belongs. This may be shown diagrammatically in the adjoining figure taken from the writer's " Conversion Tables " (p. 3).

[1] Conversion Tables, Hering, p. 45.

These three groups are shown by circles at the three corners of a triangle. The first and most important one, from the standpoint of the basis of a rational system, is the lower one. This is the group of absolute units. They are called so because they are the same throughout the universe, are invariable, and are independent of any constant of nature.[2] This group includes all the electrical and magnetic units, which were very fortunately and wisely based on the fundamental absolute units and are

GRAVITATIONAL UNITS and their derivatives; gram or pound as weights, foot-pounds, horse-powers, etc.

Mechanical equivalent of heat.

Acceleration of gravity.

Specific heat of water.

HEAT UNITS and their derivatives; calorie, thermal unit, thermometer scale, etc.

LIGHT UNITS and their derivatives; candle power, lux, etc.

ABSOLUTE or ELECTRICAL UNITS and their derivatives; gram or pound as masses, dyne, centimeter, foot, second, watts, joules, etc.

therefore fixed and invariable and are independent of any constant of nature.[3] They also include the gramme or pound considered as mass as distinguished from weight, the dyne, erg, centimetre, foot, second, etc. All these units, being invariable, and being independent of the determination of any constant of

[2] Exception might be taken to saying that our unit of time is independent of a constant of nature, because it is based on the revolution of the earth around the sun; but unlike the mechanical equivalent of heat, the specific heat of water, the acceleration of gravity, etc., that constant of nature has been determined with very great accuracy and may therefore safely be assumed to be known absolutely. But whatever that constant of nature may be, the second of time is at least a unit which is invariable throughout the universe. Time is, by general agreement, accepted as one of the three fundamental absolute units in the c.g.s. system.

[3] Exception might be taken to this on the ground that the specific inductive capacity and the permeability of air are involved in some of them; hence some of them might be different elsewhere in the universe. But their relations are at least definitely known, without having first to determine those constants of nature. Moreover, these two constants of air are apparently so little different from those of a vacuum that no appreciable error is made by neglecting the difference.

nature, form the best group and the one on which all other units should be based as far as practicable.

The second most important group is that of the gravitational units.   These all involve the constant of nature called the attraction of gravitation of our earth; they are therefore purely terrestrial units and would be different on other planets.   They are in fact slightly different even on different parts of the earth. They include such units as the gramme or pound considered as weights, hence the horsepower, the foot-pound, etc.   Their values depend upon the constant of nature called the acceleration of gravity; hence they are known only to the same accuracy as that constant is known.   It can be shown that this constant is the connecting link between this and the first group (the absolue units); hence knowing this constant, the absolute values of all the units of this group can be established.   Had our forefathers based the gramme or the pound as weights, on a more rational basis than the attraction of our own earth, as was subsequently done in the establishment of the units of force called the dyne and the poundal, our system of measures would have been relieved of this whole group, hence simplified by $33\frac{1}{3}$ per cent.

The third group is that of the thermal units.   It embraces such units as the calorie, the British thermal unit, the thermometer scales, etc.   They have been based on a property of water; hence for determining their value, this constant of nature must be known; and the accuracy of the units is no greater than that of our knowledge of that constant.   It can be shown that the connecting link between this group and the first one (absolute units) is the constant of nature called the specific heat of water in absolute measure.   Hence knowing this constant, the absolute values of the calorie, the British thermal unit, etc., can be established from the absolute units.   Had our forefathers based the calorie or the British thermal unit on a more rational basis than a property of water, as was subsequently done in the establishment of the unit of energy (therefore including heat) called the erg or the joule, our system of measures would have been relieved of this whole group, hence simplified by $33\frac{1}{3}$ per cent.   In an entirely new system of units there seems to be no reason why both of these groups should not be eliminated, thus simplifying our systems by $66\frac{2}{3}$ per cent.   This is done in the c.g.s. system of units which is a specific set of absolute units.

The two constants of nature mentioned above are moreover the only ones necessary for connecting the units of these three groups with each other, that is, for converting quantities in terms of one unit, into their equivalents in terms of another. As these two constants rigidly connect these two groups with the first one, the two former must thereby be rigidly connected with each other. This connecting link between the second and third groups is another constant of nature called the mechanical equivalent of heat. The latter is equal to the specific heat of water divided by the acceleration of gravity.

The light units have in this diagram (p. 134) been shown as a fourth group. They were originally based by our forefathers on the arbitrary " candlepower " which has no known relations to any of the other groups of units, hence they form a group separate and distinct from all the others. It is unfortunately not possible with our present knowledge to convert a unit of light flux (a lumen) into watts, calories per second, or horse-powers, as neither of these three connecting links is known. The determination of any one of the three would establish the other two. This would mean the determination of the electrical, thermal or mechanical equivalent of light. If light is considered a physiological phenomenon, there might be difficulty in establishing such an equivalent; but by defining the unit of light flux in terms of some fixed wave-length, it seems that such an equivalent could be determined; light of other wave-lengths would then have to be referred to this one by means of factors.

The group of light units affords a good illustration of a case in which it is still within our power to simplify the system of units, as was suggested by the writer when this diagram was published seven years ago; the light units are not yet in such extended use that it would be useless to try to introduce a better system.

If instead of defining arbitrarily some unit of light and after-wards finding its connecting link with the other group of units (as was done with the other two groups), the unit of light be originally defined in terms of the absolute system (as was done with the electrical units), and its light value determined after-wards (as was done in the case of the ohm and the ampere), then this group would come under the group of absolute units.

An ingenious method of doing this was suggested by Dr. C. P. Steinmetz several years ago.[4] He there proposed to make the unit of light flux equal to one watt by definition, and then to determine the light produced when all of this power was converted into light. As the watt is an absolute unit, this would bring the light units into the group of absolute units.

The above analysis in connection with that diagram show the nature of some of the possible simplifications of our system of units, and the unwise methods that have been used in the past. It teaches us what to avoid at the present and in the future. While we cannot expect to correct these unfortunate errors of the past by any sudden revolution in our system of units, yet it is within our power to favor the simpler system by using it in preference to the older, more complicated one whenever practicable; the advantages would then be appreciated and the example would be likely to be followed by others.

As an illustration, calculations concerning electric furnaces involve quantities of heat. If the unit of heat is taken as the joule, instead of the calorie or the British thermal unit, and that of the flow and of the rate of producton of heat is taken as the watt instead of the calorie per second, both of which of course would be quite correct,—it at once brings the thermal units into the group of absolute units and thereby avoids using the troublesome numerical conversion factor which connects these two groups. The relations between the units then becomes unity, as it is in the system of electric units, and all calculations are thereby very greatly simplified. In calculations involving only heat and chemical energy, the calorie and British thermal unit are to-day the simplest ones to use, because the tabular data are at present generally given in terms of them, but there seems to be no good reason why such data should not also be given in joules. It is not recommended here to make all calculations in the absolute units, but merely to do so by preference when there is a choice; in this way we may hope that at some future time this ideally simple system will come into general use.

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[4] " Primary Standard of Light," Trans. Amer. Inst. Elec. Eng., 1908, vol. xxvii, part 2, p. 1319. See also deduction from it in article " On the Relations of the Measures of Light and Power," Hering, Elec. World, Sept. 19, 1908, p. 621.

The above has shown how certain complications may be avoided by not establishing new groups of units on different bases, connected together by incommensurate constants of nature, as was formerly done.

Another simplification, and an important one which might often be made use of to-day, is to adopt only one unit for each physical quantity. Exceptions may and unquestionably are justified when, to eliminate the troublesome factor π, two units are adopted for the same physical quantity, as for instance in the square mil and the circular mil, the degree and the radian, the gilbert and the ampere-turn, the lumen and the spherical-candle, etc., as will be discussed later. It is also understood here that such decimal multiples as kilometre, centimetre, etc., are considered as one unit, the metre; and that the erg and joule are the same unit, as the latter is just ten million times the former.

The simplest illustration of the above is that we should adopt some one unit of length, like the metre, and drop all others like the inch, foot, yard, mile, etc. But in these common units this is already well understood and needs no further mention here. It is, however, not so evident in the less common units and it is with some of these that important simplification becomes possible, and would be easier to introduce than changes in such deep rooted units as the inch, pound, etc. Among these may be mentioned the following:

Energy is the same physical quantity whether it appears as mechanical, thermal, luminous, electrical, magnetic, chemical, or acoustic energy; hence in all of its forms it could be measured in terms of one unit and in fact is so measured in the absolute system by the erg. Instead of this one unit we now use the foot-pound or kilogramme-metre, the British thermal unit or calorie, the lumen or spherical-candle, the joule, etc. To some extent the use of some of these may still be justified because it would involve a too radical (though still very desirable) change to be practicable as long as we adhere to the older systems. But in some respects it would be quite possible and not at all impracticable to make changes in this direction now. The heat units, for instance, might well be abandoned entirely and replaced by the larger absolute unit, the joule, which may be said to be the same unit as the erg. This would merely require the tabulated values, such as those of specific heats, latent heats, chemical

energy, etc., to be recalculated once for all, after which all electro-thermal calculations would be reduced to the ideal simplicity of the other electrical calculations, and the specific heat of water (in absolute measures), besides both the electrical and the mechanical equivalent of heat, would be eliminated from all such calculations; the relations between electrical and thermal energy would then all become unit relations, which is the ideal. This would be of great value in electric furnace calculations.

If furthermore the suggestion of Dr. Steinmetz above referred to were introduced, all calculations connecting light energy with electrical energy would be reduced to the same ideal simplicity of unit relations.

If finally weights when considered as forces (as they always are in all calculations of mechanical energy) were expressed and measured in absolute units of force, such as the dyne, or its multiple the megadyne, then this group of calculations would also be reduced to the ideal simplicity of unit relations, as a dyne acting through a centimetre generates one erg of heat energy. The group of gravitational units would then be brought into that of the absolute units.

Although some of these changes would be too radical to be introduced at once, yet if it be recognized and remembered that this is the proper direction of development toward very desirable simplicity, and if the leaders in their respective professions would adopt and gradually introduce the changes in these directions and teach them to their students, the reform would unquestionably be ultimately adopted, in the same way as the metric system is slowly but surely becoming more commonly used, understood and adopted. It may take generations, but in the opinion of the writer these changes are bound to come.

The same that was said about energy applies to power also, that is, to the time rate of energy. As a physical quantity, any flow or transmission of heat or of energy of any other kind, be it by conduction, convection or radiation, is power, because it is a time rate of energy, and hence is correctly measurable in ergs per second, which is merely a decimal subdivision of the watt (ten million ergs per second) or the kilowatt. Many of the calculations for electrical furnaces are reduced to ideal simplicity by representing all heat flows or streams or currents of heat, such as the heat leakage through the walls, the electrodes,

or directly by radiation, in watts instead of calories per second (or worse yet, British thermal units per second). Such flows then become directly comparable with the input of power which is always represented in watts. The complete abolition of the calorie and the thermal unit, in electrical furnace calculations, would be a simple matter; it is a good illustration of what could be done to-day very easily toward this very desirable simplification.

In this connection attention may be called to an error not infrequently made by some writers who have used the " calorie per second " as the unit of heat flow and called it the c.g.s. unit. A heat flow is physically the same as power, and the c.g.s. unit of power is the erg per second and not the calorie per second. This is another instance of departing from, instead of leading to, the ideally simplest system.

Light radiation or luminous flux is physically also exactly the same kind of a quantity as mechanical power, and with properly chosen units could also be measured in absolute power units, ergs per second or watts. Now such radiations are measured in lumens or spherical-candles, but if this unit of light flux had originally been made a watt or some decimal of it, all such cal- culations concerning luminous power would have been reduced to the ideal of simplicity of unit relations. Here, however, the numerical equivalency,—which, analogously to the term mechan- ical equivalent of heat, would be called the electrical equivalent of light,—is still unknown, and until it becomes known the light units and calculations cannot be reduced to this ideal simplicity. If the plan of Dr. Steinmetz referred to above were carried out, namely, to make the unit of light flux equal to one watt, by definition, and then determine the candlepower value from this, as was done with the electrical units, the reduction to unit rela- tions would be complete. Until then we must continue to express this relation in terms of the ratio of lumens to watts.

Electric power is always expressed in watts, and hence calcu- lations concerning it have already been reduced to ideal sim- plicity. The same is true of magnetic power, such as is trans- mitted from the primary to the secondary of a transformer. Mechanical power is still expressed in horsepowers, but a change to kilowatts has already begun when such power is to be con- verted into electric power. Lastly, chemical power, that is, the rate at which chemical energy is set free or consumed, as for

instance in combustion, explosion, chemical changes in furnaces, or if purely physical as in refrigeration, could quite as well be to-day expressed in watts instead of calories per second, thereby bringing all these calculations into the group of simple unit relation units.

Besides these cases of energy and power units, there are numerous others in which we are now using two or more units when one would suffice, thereby not only complicating calculations but actually often giving the impression to the student that the quantities are different physically when as a matter of fact they are exactly the same.

Striking examples of this are found in the photometric units. When light issues from a surface, for instance, it is exactly the same physical quantity, namely light flux, whether it issues by reflection, as from a white wall, or by transmission, as through ground glass, or by generation, as from the surface of a source; furthermore, it is exactly the same physical quantity, before it reaches a reflecting surface as it is after reflection. Yet notwithstanding this absolute physical identity, it was proposed and recommended, even quite recently, to measure the density of this same flux by three different units, defined by different derivational formulas. This, in the opinion of the writer, is a decided retrograde step and one which could be and should be changed before it has become so generally adopted as to become difficult to eradicate. This is one of the cases which it is the purpose of this article to call especial attention to, as an illustration of how we are at the present time actually creating entirely unnecessary complications not only for ourselves but also for future generations, when it is entirely within our power to take an important step now toward simplification and rationalism, which will be bound to come later. It can be shown [5] that the complicated system of a multiplicity of different photometric quantities and units which it has recently again been proposed to adopt, really consists of a simple system of only three physically different quantities, namely flux, flux density and flux $\times$ time; in an ideal system they would be measured in watts, watts per sq. cm., and joules or ergs, respectively, or their decimal derivatives or multiples.

[5] "Calculating and Comparing Lights from Various Sources," Trans. Illum. Eng. Soc., Nov., 1908, vol. iii, p. 645.

It is presumably not disputed that in all four of the above-mentioned cases of light from a surface, the radiant energy is light flux. Then why should its density or intensity be named and measured by such entirely different names and units as " illumination," measured in metre-candles when it impinges on the surface; " radiation," measured in lumens per square metres after it is reflected by the surface; " brightness," measured in candles per square centimetre when it originates at the surface; and by several of these indiscriminately (apparently left to one's taste) when it originates behind this surface? Yet this is what has recently been recommended and endorsed.

Physically all these are true flux densities and therefore are all in fact the same physical quantity, hence measurable in the same unit, namely flux divided by the space in which it is confined; and when so measured, the relations between them at once become the simplest possible; while if not so expressed and measured their identity is not evident; on the contrary, the very fact that they are expressed by different names and units and even by different derivational formulas, naturally gives the impression that they are different physical quantities.

One of these units, namely brightness, measured in candles per sq. cm., is even worse than an unnecessary complication, as it is physically or mathematically a hybrid or inconsistency. Candlepower is distinctively a point conception, and a true point cannot have any dimensions; hence to speak of candles per area is giving a point dimension, which is a mathematical absurdity. Brightness when so defined will be found to be a quantity which is incommensurate with all the others, hence is not interconvertible with the others. Moreover, candlepower is itself a flux density, hence " candles per square centimetre " represents a density of a density, which is a physical absurdity.

When correctly analyzed it will be found that this physical quantity, brightness, is in fact a true flux density and nothing more, and is therefore measurable in exactly the same units as illumination, or as radiation from a surface. This has been discussed more fully elsewhere by the writer.[6]

It is admitted that for convenience in calculations, luminous

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[6] " Simplifying Some of the Calculations of Light." Elec. World. Sept. 26, 1908, p. 673.

flux density may be expressed and measured in terms of two different units, as will be further discussed below. The point emphasized here is that a number of ostensibly different physical quantities are in fact identical and it would simplify matters so to recognize them.

The ideal unit for all of these flux densities and the one giving unit relations with others, would be the erg per second per square centimetre, or watt per square centimetre, in terms of which the density or intensity of all transmissions of energy are measurable, whether by a belt, a current-carrying wire, magnetic flux in a transformer, heat or light flow in a body or by radiation from it, electromagnetic waves in wireless telegraphy, etc.

In connection with the flow of heat, no units for measuring thermal resistance and conductance have as yet been generally adopted, and it is therefore still within our power to establish rational ones which have unit relations, at least with the electrical quantities. A thermal resistance can be shown to be physically equal to degrees of temperature divided by watts, and a thermal conductance to watts divided by degrees. It has been proposed to call the unit based on the former a thermal ohm, and on the latter a thermal " mho," on account of their analogy to the electrical quantities. With those units, calculations of heat flows are reduced to the simplest possible, that is, to unit relations, at least when the energy is expressed in electrical units as it is in all electrical furnaces. This has been discussed and illustrated elsewhere more in detail by the writer.[7]

In still another instance entirely wrong units have been used to measure quantities, and it resulted in leading to entirely erroneous conclusions. It was required to express and measure those physical properties of a material which determined its suitability for use as electrodes of electric furnaces. Formerly it was thought that a material was better for this purpose in proportion as its thermal conductivity was lower; also in proportion as its electrical resistivity was lower; therefore measuring that quality in terms of those units. But it has recently been shown [8] that this was not correct, and that it leads to entirely

[7] " Thermal Resistance and Conductance; the Thermal Ohm and Thermal Mho," Metal. and Chem. Eng., Jan., 1911, p. 13

[8] " Laws of Electrode Losses in Electric Furnaces." Trans. Am. Electrochem. Soc., 1909, vol. xvi, p. 265.

erroneous conclusions. It was shown that the correct units are two entirely different ones. The correct one for measuring that physical quality of an electrode material which determines the loss of energy in it (when operating under the ideal conditions) is proportional to the square root of the ratio of the thermal to the electrical conductivity; while the correct unit for measuring that quality which determines its size is proportional to the square root of the reciprocal of the product of the two conductivities. Hence neither conductivity alone is any criterion, it is the square root of their quotient and of their product which governs the results.

This is cited here merely to show the grave errors which can arise when in the more complicated cases sufficient care is not taken in the proper selection of the correct units; also as another instance in which the choice of new units gives us an opportunity to select those which will reduce calculations to the simplest possible, namely to those in which there are unit relations, as the thermal conductivities can in this case be to great advantage represented in terms of the electrical units, watts.

When there is any doubt as to the true physical nature of a quantity it may generally best be determined by deducing its so-called " dimensions " [9] which will at once show it. Great care must; however, be taken, as errors are easily made resulting in absurdities due to the neglect of quantities whose numerical values are unity in a formula, or to the neglect of the so-called " suppressed quantities," or sometimes to the unfortunate inconsistency that the dimension of an angle in this system is unity and therefore is not noticed.

In general therefore, as has been shown above, it will greatly simplify our measures, and should therefore be very desirable, to select one and only one amount of each physical quantity as the unit for measuring it. There are, however, important justifiable exceptions. Units are not only for expressing amounts of physical quantities, but also for making computations in which those amounts are involved. Hence an important feature in the selection of a unit for an ideally perfect and simple system is to make it as convenient a one as possible for calculations. In some

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[9] For a tabulated list of such dimensional formulas classified according to their dimensions, see this Journal, Sept., 1910, p. 194.

cases it is therefore very desirable to have two numerically different units for the same quantity, they being so chosen that each is the simplest possible one for each one of two groups of calculation.

The chief reason for this is the fact that the ratio of the diameter to the circumference and area of a circle or of a sphere, are incommensurate, and that calculations from one to the other involve this factor π in various forms. It is of course impossible to eliminate this constant of nature entirely, but it is quite possible to eliminate it from a very large number of calculations by using two units differing from each other by this factor in its various forms, so as to enable us to use either one or the other, whichever involves the least calculations.

A good illustration is the square inch and the circular inch; both are units of area; the latter is the most convenient to use for circular areas and the former for all others. In circular pipes, for instance, the area of cross section in terms of circular inches is equal simply to the square of the diameter, thus eliminating π from all that very large group of calculations.

Another such justifiable case of double units is the gilbert and the ampere-turn, for measuring the magnetomotive force. The gilbert is the absolute unit, hence the more rational one for an interconnected system of units having unit relations; but the ampere-turn is generally the simplest one to use because it eliminates the troublesome factor π from a relatively very large group of such calculations. A gilbert is equal to $10/4\pi$ ampere-turns.

Another instance is the radian and the whole circle, for measuring arcs or angles. Sometimes the one and sometimes the other is the simplest to use. They too differ by π, a complete circle being equal to 2π radians. The degree has not been included here as an angular unit, as it is irrational and avoidable, and should have been some exact decimal subdivision of a whole circle, as for instance $1/100$ or $1/1000$.

Another good illustration of the great value of double units to eliminate π from calculations, are the two units of light flux, the spherical-candle and the lumen. Both are true and correct units of flux, being both rates of propagation of luminous energy, or physically the same as power, hence also measurable in watts

or ergs per second. Again they differ by the factor π, a spherical-candle being equal to 4π lumens. Either can be used in calculations, whichever reduces the computations to the simplest possible. If only one were used, it necessarily follows that many of the calculations would involve multiplying or dividing by 4π, when this additional calculation might just as well have been dispensed with, just as in the use of circular mils for square mils in calculations involving the cross section of round wires. In the case of the spherical-candle the unit of the solid angle used is the whole sphere, just as in angular revolutions per minute the complete circle is used as the unit of plane angles. While in the case of the lumen, the unit of solid angle used is the absolute one, namely, a certain fraction of a whole sphere equal to $1 \div 4\pi$.

This is a good illustration of a case in which a reform tending to simplicity of calculations might be introduced at once, without disarranging any long-established system. Many calculations are to-day made in terms of the unit lumen, which would be greatly simplified by using the other and more suitable unit, the spherical-candle.

Another important case of justifiable double units is that of luminous flux density. At times (when the light issues from a point) it saves calculation to express this density in terms of a solid angle, hence the unit of density or intensity called the candlepower. At other times (when the flux impinges upon, passes through, or issues from a surface), it is more convenient to express this density in terms of a flat surface, hence the unit foot-candle, called illumination. Both are very useful and we could not do well without either.

Another illustration of a double unit is the coulomb and the ampere-hour (the latter equals 3600 coulombs). This, however, differs from the others in that it would be within our power to simplify it by simply making the units of time decimal multiples of each other. Hence this double unit is justified only because we have to use an irrational set of units of time.

In conclusion a few words may be said about the naming of units. An unnamed unit is like an unnamed tool, it cannot be referred to or specified clearly and definitely, and when the units in terms of which any results or formulas are given are not

understood beyond doubt, the usefulness of such results generally
suffers greatly if in fact it is not entirely destroyed.

In general it seems very much better, in view of the large
number of names which one has to learn, to make the name of a
unit self explanatory, whenever the nature of the unit permits it,
and when the name does not become too long.   For instance,
" foot-pounds," " miles per hour," " pounds per square inch,"
" r.p.m." standing for " revolutions per minute," " atmosphere "
(pressure), " B.T.U." standing for " British thermal unit,"
" steradian " standing for solid radian, etc.   In all such com-
pound names the universal custom is that a hyphen means the
product of two units, while the word " per " means the quotient
of the first divided by the second.   In all such cases no explana-
tion of the units is necessary; and it is not necessary to look
them up in reference books.   Units so named adapt themselves
automatically to the metric and the English system.   Hence
specific names in such cases are unnecessary and generally inad-
visable; and when they are given it is likely that they will never
be universally adopted; the name " barie " for pressure, " kine "
for velocity, are good illustrations of unnecessary names.

There are some cases, however, in which such compound
names would be more likely to confuse than to be self-explana-
tory, and it is then preferable to give them a specific name.   An
electric current, for instance, is the ratio of the electromotive
force to the resistance, hence if only the two latter were named,
the unit of current would be called " volts per ohm "; this is
not only confusing but does not in itself suggest a current.

When a unit is used very frequently, like the three chief
electrical units, a specific name is decidedly preferable, even
though the act of learning them the first time may give a little
trouble.   It is when such specific names become very numerous
that they may be justly objected to.

Custom may often be relied upon to decide whether a specific
name is advisable or not.   The unit of magnetic flux, for instance,
has been given the name of maxwell, but this has not replaced
entirely its former self-explanatory though longer name " line of
force."   Naming units after distinguished pioneers, as was done
in the case of the electrical and the magnetic units, seems to be a
commendable custom provided it is not carried too far.

When analytical investigations are made without reference to any specific units, it is usual to claim in a general way that the " absolute " or the " c.g.s." units are understood. This is generally safe because the relations in that system are usually unit relations, and whatever may be the physical quantity (even if its nature is unknown) there generally must be some one and only one unit in that system, for measuring that quantity. This has become a habit and as such has led to carelessness, as in the case above cited in which " calories per second " were incorrectly termed the c.g.s. unit, when the latter really is the " erg per second."

As many of the c.g.s. units have no names and as it is often very convenient to refer to them by name, the commendable suggestion was made some years ago by Dr. A. E. Kennelly, to designate them by prefixing " ab" or " abs" to the name of the carresponding practical or working unit, as for instance abvolt, absohm, etc., when referring to the electromagnetic system, and " absta " or " abstat " when referring to the electrostatic system.

In a subsequent article the writer intends to show by specific illustrations how by only slight modifications in our present system of units a very great step could be taken toward this ideal system in which calculations are reduced to the simplest · possible by the reduction of all relations to unity or to powers of 10, like in the system of electrical units.

Summary.—In the above the writer has endeavored to show by an analysis of our systems of measures and units, that many of the numerous every-day calculations of the engineer, which must be made with such units, could have been greatly simplified and their clear understanding facilitated and enhanced, had the systems by which some of these units were originally designated been more rational and consistent ones. While it is admitted that it might be too revolutionary to change our present irrational system to the rational one by a complete and radical transformation, yet this very desirable change, which is bound to come in time, could be greatly encouraged and accelerated by continually keeping the ideal system before us in our minds, teaching it to students, and approaching it at every possible occasion by small but positive and decided steps in the right direction, and by all means not making existing matters worse by taking

any steps in the wrong direction, away from this path to the ideal. A close approximation to this ideal system is already in extended use among physicists under the name of c.g.s. system, and there appears to be no reason why engineers, who apply physical laws to practical problems of construction, should not also enjoy the advantages of similar simplicity in their practical work.

Iron Ore Resources of the World. L. DE LAUNAY. (*Iron Age,* lxxxvi, 12.)—An article worthy of close consideration by iron producers and users. M. de Launay refers also to probable new iron ore development, after the reserves now in sight are largely exhausted. Northern Sweden contains large quantities of rich iron ores of more than 60 per cent. Recently iron ores have been discovered in the Lake Superior region, known to contain 2,000,000,000 tons of metallic iron, with a possible 36,000,000,000 tons. When Canada is explored, no doubt important discoveries will be made there. Newfoundland appears to have almost 2,000,000,000 tons of iron ore containing 65 per cent.; and similar ores are abundant in the Adirondacks. In the Southern Hemisphere, Minas Geraes is to be taken into account. For lower grades of ore, France may take the most prominent position with its supplies in Lorraine, Normandy and Algeria; followed by Germany with its ores found in German Lorraine.

The Mechanigraph. (*Iron Age,* lxxxvi, 13.)—This machine renders an opaque pencil or pen drawing transparent and printable practically instantaneously, at a cost of approximately one-third of a cent. per square yard. The drawing to be treated is passed through the first pair of rolls which carry it through the bath containing the transparantor liquid, and from there along the moving tapes to the drying rollers, which are warmed by a current regulated by the rheostat beneath. The pressure on the drying rolls is maintained by adjustable, spherical iron weights.

Hypochlorite Treatment of Water Supplies. GEO. A. JOHNSON. (*Eng. Record,* lxii, 12.)—In view of the belief gradually gaining ground that mere filtration through sand is by no means a certain arrester of bacteria, and thus is unreliable as a water purifier, the above paper on the use of hypochlorites as a germicide is of interest. Mr. Johnson summarizes the advantages of the process thus:

1. Substantially complete destruction of objectionable bacteria particularly those of intestinal origin.

2. Reliability and ease of application of the chemical and small variation of required dose.

3. Absence of poisonous features, either in the chemical or in its resultant decomposition products.

4. Nominal cost both of chemical and its application.

5. Speed of reaction, requiring no substantial basins other than storage facilities.

6. Saving in cost of coagulation of waters requiring clarification or filtration.

7. Permitting a very high rate of filtration, with high bacterial efficiency.

8. Reduces clogging of filter beds, and lengthens runs between cleanings, by destroying various forms of algæ.

Its limitations are: Inability to remove or destroy (1) all of the spore forming bacteria (these are not considered pathogenic to man), (2) bacteria imbedded in suspended water, (3) inability to remove turbidity or (4) appreciable amounts of color, or (5) organic matter, or (6) swampy tastes or odors, or (7) creosote tastes or odors, and (8) inability to soften water, and (9) difficulty of application to waters containing reducing agents.

Blistering of Sterling Silver during Annealing. ANON. (*Brass World,* vi, 349.)—It is possible to produce blisters on perfect sterling silver by overheating it during annealing in an oxidizing atmosphere. It is generally assumed that the blisters are the fault of the metal itself, and are caused by careless or imperfect melting; this is asserted to be radically wrong. Experiments show that sterling silver cannot be blistered when a reducing flame is used for annealing, but an oxidizing flame produces numerous blisters. The theory is advanced that silver absorbs oxygen energetically when the temperature approaches the melting point.

Slow Rusting Iron Produced in the Open-hearth Furnace. ANON. (*Eng. News,* lxiii, 6.)—" American ingot iron " has recently been placed on the market by the American Rolling Mill Co., which exhibits a high resistance to corrosion and is therefore valuable as a structural material. Although produced by the basic open-hearth process it is closely similar to wrought iron. It differs from steel in that its contents of carbon, manganese, and silicon are only fractions of the amounts in ordinary soft steel. In appearance, strength, and ductility this is practically identical with wrought iron. The usual ferromanganese recarburizer is omitted and ferrosilicon, or an equivalent, is used to purify the bath of its oxides. Aluminum is added in the ladle to carry off the gases dissolved in the fluid metal. Relative corrosion resistance tests with sulphuric acid show that ingot iron has 40 to 60 times the resistance of steel, and 20 to 40 times the resistance of wrought iron.

THE COPPER DEPOSITS OF FRANKLIN-ADAMS COUN-
TIES, PENNSYLVANIA.

BY

EDGAR T. WHERRY, Ph.D., Lehigh University.

*(Presented at the meeting of the Mining and Metallurgical Section,
Thursday, May 19, 1910.)*

THE existence of copper ores in the South Mountain range of
south-central Pennsylvania and northern Maryland has long been
recognized. The numerous abandoned workings to be seen
throughout the region indicate that considerable amounts of
money have been wasted in vain attempts to win the metal, and it
may well be doubted whether deposits of sufficient magnitude
to repay operation can have escaped discovery. Nevertheless the
renewed activity in prospecting exhibited during the past few
years has attracted considerable attention to the district, and the
results of a hasty examination made during October, 1909, seem
accordingly worth placing on record.

HISTORY.

The presence of valuable metals in the region was noted as
early as 1787 by the German traveller Schöpf, who in his descrip-
tion of the American Colonies [1] stated that " The South Mountain
in its entire extent contains rich crevices, gangues, and nests of
ore, especially of iron and copper." It is said that mining was
begun about 1810, and in his report of 1858 Henry D. Rogers [2]
described the results as follows: " Near Miney Run search was
made many years ago for copper ore, but nothing was found to
justify the expectation of finding a productive vein of that min-
eral. A small quantity of copper ore was once obtained, and a
furnace built for smelting it, in a small ridge north of Jack's
Mountain, but the exploration was abandoned. The metal occurs
in the form of a green and blue carbonate, with a little native
copper. Evidently the ore is not abundant."

The next thirty years witnessed repeated attempts at mining

at various points, but so far as recorded in the scattered publica-
tions on the subject listed in the bibliography none of them repaid
in any degree the cost of development.   In 1892, when a detailed
geological examination of the region was made by Miss Bascom,[3]
all were abandoned, but since that time there has been a revival
of interest, and at present operations are being carried on in
several localities, although the results are as yet not particularly
encouraging.

GEOLOGY.

Much of the description herewith presented, as well as the
greater part of the mapping, have been taken from the paper by
Miss Bascom, above noted, which left little to be desired as to
our understanding of the geology of the district.   A somewhat
different interpretation of certain of the igneous rocks is sug-
gested, however, and a more detailed inquiry directed toward
the probable origin of the copper ores.

Three distinct formations are present,—a clastic rock, a basic
igneous rock and an acid igneous rock.   The first consists of a
series of conglomerate and sandstone beds, capping the higher
ridges and hills.   The constituent grains are chiefly fragments
of the igneous rocks now exposed in the valleys, over which it
lies unconformably.   Its thickness is not far from 1000 feet,
and fossils it contains show it to be of Lower Cambrian age.

Since both of the igneous rocks are represented in the basal
Cambrian conglomerates, they are both to be regarded as pre-
Cambrian in age, although no definite correlation of them with
formations of other regions is thereby implied.   The basic rock
is for the most part a dark green schistose material, to which
the term greenstone may be appropriately applied.   Locally it is
massive, and then has the character of a basalt; and microscopic
examination of the schistose portions show them to have been
formed by metamorphism of the same rock.   While chlorite
is the usual dark silicate, epidote is also abundant in some places,
and as the copper ores are largely associated with this mineral,
its occurrence will be more fully described below.   Numerous
amygdules of quartz, epidote, or calcite testify to the original
effusive character of the rock, and there can be no question that
it represents an ancient lava flow.

The greater part of the acid igneous rock gives evidence of

a similar origin.   The large northeastern body contains abundant
amygdules, spherulites, lithophysæ, and various types of flow
structures, all of which are characteristic of lavas.   Certain iso-
lated masses show, however, none of these features, but are in-
stead quartz porphyries, and these have been distinguished on
the accompanying maps, being regarded as dikes rather than over-
flow sheets.

The question as to the relative age of these lavas is one of
considerable interest and importance, but the evidence at hand is
unfortunately not sufficient to decide the question finally.   Miss
Bascom was inclined to consider the acid one as the older, because
of (*a*) four exposures of basic overlying acid rocks, and (*b*)
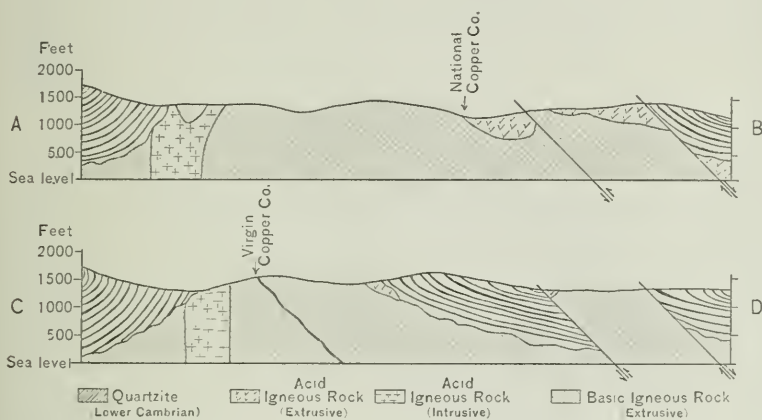
HYPOTHETICAL STRUCTURE SECTIONS OF SOUTH MOUNTAIN COPPER DISTRICT

the generally higher elevation at which the basic rocks occur.   In
the present paper the reverse succession is favored because (*a*)
in at least two of the points of contact above mentioned the acid
rock is of the quartz porphyry type regarded as characteristic of
dikes; (*b*) the higher levels at which basic rocks appear may be
the results of folding or faulting; and (*c*) at one locality, the
National Copper Company's mine, there has recently been ex-
posed a contact of typically extrusive phases of both rocks, and
the acid overlies, the contact plane dipping 30 degrees to the
southeast.

The greenstone in this exposure, which consists of an open
cut 50 feet long and as much as 30 feet deep, is so completely

MAP OF THE
SOUTH MOUNTAIN COPPER DISTRICT
FRANKLIN-ADAMS COUNTIES
PENNSYLVANIA
GEOLOGY FROM UNITED STATES GEOLOGICAL
SURVEY BULLETIN 136
WITH ADDITIONS BY
EDGAR T. WHERRY
1909-1910

Quartzite Lower Cambrian
Acid Igneous Rock-Extrusive
Acid Igneous Rock-Intrusive
Basic Igneous Rock-Extrusive
⚒ Mines and Prospects
—————— Inferred Faults

0   ½   1 mile

Snively Mine

Green Ridge

Bechtel Mine
South Mountain
Copper Co.

Russell
Mine

Kepner Knob

Franklin Co.
Adams Co.

Virginia's
Rock

Reed Hill
Copper Co.

Bigham Mine or
Copper Furnace
National Copper Co.

A   B

C   D

Virgin
Copper Co.

Pine Mountain

Jack's Mountain

Gladhi
Sta.

Tunnel

Monterey
Peak

Headlight Mine

WESTERN MARYLAND RAILROAD
BALTIMORE AND HARRISBURG DIVISION

Fountaindale

Charman
Sta.

Franklin Co.
Adams Co.

Eagle Metallic
Copper Co.

Haycock
Mountain

Raven Rock
Mountain

Blue Ridge
Sta.

PENNSYLVANIA
MARYLAND

sheared to a chlorite schist that its original character is inde-
terminable, but it shows some amygdules, and could well enough
be the upper surface of a lava flow.   The acid rock is a gray rhyo-
lite yielding fine thin sections (several of which are figured in
Miss Bascom's paper) showing an original spherulitic structure
partially obscured by the development of quartz and feldspar in
place of the ground mass, and elongated vesicles filled with
epidote surrounded by a rim of quartz and occasionally contain-
ing grains of metallic copper.   While these features suggest the
top rather than the base of a lava flow, the under-rolling of a crust
may bring vesicular phases to the base of an advancing lava sheet,
or if composed of successive thin flows it might be vesicular
throughout.   There is thus nothing visible here opposed to the
view that this represents a normal contact between the two lavas,
which would certainly make the basic one the older.

ORE DEPOSITS.

Mineralogy.—The most abundant and characteristic ore is
native copper, which is present in every known deposit, and is in
most of them the only mineral of value.   It appears chiefly in
small stringers and grains, traversing crevices in the rocks, but
occasionally forms masses of large size, rounded lumps of several
pounds in weight having occasionally been observed.   So far
as noted it shows no tendency to assume a crystal form of its
own, the shape of the fragments being always that of the cavity
occupied.

Chalcocite is not uncommon as minute scattered grains
through the greenstones, but nowhere appears in sufficient quan-
tity to constitute an ore.   At the Eagle Metallic Copper Com-
pany's mine much of what was taken for chalcocite is actually
specular hematite.   Cuprite is present surrounding specks of
native metal in the amygdules at the National Copper Com-
pany's property, and has probably been derived, like the asso-
ciated carbonates, by partial weathering.

Malachite stains are evident everywhere at the outcrops of
ore-bearing rocks, especially where chalcocite has been present;
the native copper itself has rarely been affected by the atmos-
phere.   Azurite and chrysocolla are less common, although at
the National Mine their presence as thin films in joint cracks gives

rise to rather showy specimens. Minute crystals of both azurite and malachite occur here in some of the amygdules.

The most frequent associate of the copper minerals is epidote, which exists as a secondary replacement of the minerals of the greenstones, as well as a filling mineral in the amygdules. It is usually massive-granular, distinct crystals being quite exceptional. Cryptocrystalline vein-quartz is abundant, and the native copper is largely associated with it. Opaque white cleavable calcite is also present in some veins, notably at the Virgin Copper Co.'s Mine. Minute scales of specular hematite occur in the vein-quartz at several points, and as noted above have been mistaken for chalcocite at one mine. Asbestos in long silky fibres and dark green flaky chlorite complete the list of accessory minerals.

OCCURRENCE AND ORIGIN OF THE ORES.—While three types of occurrence of the copper minerals may be distinguished, there is no reason to suppose them to be distinct in origin, but on the contrary they show gradation from one to the other. In the first type grains of chalcocite are embedded in schistose chloritic greenstones, representing replacements of original silicates, or fillings in the amygdules. The malachite stains observable at so many exposures of the greenstones are in practically every case the result of the action of the weather on this class of material.

A second kind of deposit is the epidote vein type, which is represented in most of the mines of the region. It consists of layers or zones of greenstone high in calcium, so that the original rock constituents are largely replaced by epidote instead of chlorite, while the amygdules may be occupied by epidote or calcite. In these epidote-bearing layers there are numerous quartz veins, carrying native copper in relatively large amount; although the copper may also extend out into the rock itself, especially where it is shattered or otherwise porous.

In the third type, native copper and its alteration products occur in amygdules in the acid lavas near their lower contacts upon the basic ones. Stains also appear on the latter, however, and their cavities may contain the metal as well.

That the original source of the copper has been the basic lava now in the form of greenstone appears to be the most plausible interpretation of these deposits. The arguments in its favor consist in: (a) the practical limitation of the ore-bodies to this

rock; (b) the presence of minute amounts of copper as a constituent of its ferromagnesian minerals; (c) the similarity of this to other regions where such an origin is considered certain. Against it may be urged: (a) that in several places ores lie at or near contacts with the later acid volcanics, suggesting introduction of the metal by the latter; (b) that a complex and intricate motion of waters must apparently be appealed to in accounting for the concentration into the existing masses.

Taking up these points in order, the relation indicated in (a) is recognized by all who have had occasion to examine or prospect in the region. The appearance of green stains at nearly every exposure of the basic rocks, at least within the main area in the southwest portion of the region, and their total absence from the acid ones, except at one or two contact localities, is very striking. It might be suggested, to be sure, that some chemical feature of the former rocks, such as abundance of ferrous iron, has enabled them to act as a precipitant for copper, rising, perhaps, from a deep-seated source. There is, however, nothing in the distribution of the metal, and especially, no visible connection between its points of occurrence and prominent fissures, to justify such an assumption.

(b) With a view to determining to what extent copper is present in the basic lava itself, chemical examination was made of two samples, both taken from localities well removed from any known deposits of the metal. In one specimen 0.27, in the other 0.08 per cent. of copper were found; and as this proved to be insoluble in nitric acid, it cannot be due to disseminated chalcocite or native metal, but must be a constituent of the dark silicates of the rock.

As to (c), the similarity of these deposits to those of the Lake Superior Region is so marked that at least one early observer attempted exact correlation of the two occurrences.[4] And the resemblance to those in the Kotsina-Chitina Region, Alaska, as described by Moffit and Maddren,[5] is no less striking. While we can no longer agree with correlation on mineralogic or lithologic grounds of rocks so widely separated geographically, it can hardly be doubted that the chemical processes concerned in the concentration of the ores were closely analogous in the several cases, and the conclusions as to the source of the metal arrived at by those best qualified to judge with respect to one of these

localities are surely deserving of considerable weight in forming
any theory as to another. Wadsworth, Lane, and many others
agree in attributing the copper to the ferromagnesian constit-
uents of the igneous rocks in the Lake Superior Region, even in
the face of the known existence of occasional veins suggesting
a deep-seated source; and a like interpretation would seem still
more plausible here, in the absence of any well-defined fissures.

Objection (a), that many ore bodies occur at or near con-
tacts of the two igneous rocks, is of little weight, since such
nearness to the contact is for the most part only an accidental
circumstance. Thus the deposit being explored by the Virgin
Copper Company, while less than a hundred feet from such a
contact, not only shows no connection with it as far as distribution
of the metal goes, but is also identical in character with several
others throughout the greenstone belt, some of which are far re-
moved from any known mass of acid rock. While at the
National Copper Company's mine, the only place where the
actual contact relations are exposed, the metal occurs in both
rocks, and might have originated in either one equally well.

A consideration of the process of concentration of the metal
will show the weakness of objection (b) also. It may be re-
garded as probable that the copper has been introduced simul-
taneously with the vein quartz and calcite because of its intimate
admixture with them. As Van Hise has pointed out,[6] the
silica which fills up the great majority of crevices in rocks which
have remained for any time in the " belt of cementation," that
is, from between about 1000 and 30,000 feet below the surface,
has been chiefly derived from the rocks nearer the surface, from
which the carbon dioxide of the atmosphere has liberated silica in
the colloidal state. The precipitation of this silica is, however,
not so much a chemical as a physical process, the character of the
material already present in the solid state determining the charac-
ter of the substance separating, so that sand grains may be
secondarily enlarged, and, in general, material originally distrib-
uted through a body of rock may gradually become segregated
into a few large masses in obedience to the principle that large
grains grow at the expense of small ones, without any circulation
of water being called for, but only the operation of the process of
diffusion.

If we admit that the quartz veins have been formed in this

way, it seems only reasonable that the same principles should apply to the so closely associated native copper. But we must first be certain that this interpretation does not disagree with the chemical features of the deposits. For example, the constant association of copper with epidote—a relation so evident that the epidotized layers are called by local prospectors " copper rock "—is it not possible that the epidote may have acted as a precipitant for the metal? Such a conclusion is, however, chemically unsound; epidote contains but small amounts of ferrous iron, and no other constituents capable of bringing about reduction, whereas the chlorite making up a considerable proportion of the body of the rock may carry as much as 10 per cent. FeO, which should render it far more effective as a reducing agent. A little reflection shows, on the other hand, that the association of the copper and epidote may be entirely a physical phenomenon. During the intense earth movements to which the region has been subjected, the chloritic portions of the rock mass have " flowed," producing the southeast dipping lamination everywhere apparent; while the layers rendered hard and brittle by the presence of the epidote have been, by the same forces, cracked and shattered, the open spaces thus produced being filled by vein quartz and copper simply because they were open spaces.

The existence of the greater amount of copper as the native metal rather than as a compound is also, here as in the Lake Superior and the Alaska district, in need of explanation. The view held by Pumpelly[7] and others, and experimentally verified by Stokes,[8] that ferrous compounds can reduce copper to the metallic state, is unquestionably an adequate cause of this condition, yet we do not find the metal surrounding masses of ferrous minerals, but, embedded as it is in vein quartz in turn surrounded by epidote, it is about as far removed from them as it could possibly get. The only reasonable explanation of this state of affairs is that the copper has not been transported as sulphate, as commonly assumed, and deposited by reduction, but has been carried to its present position as a dilute solution of the metal itself, the reducing power of the ferrous iron having made itself felt at the time of breaking up of the original copper-bearing silicates. The process of diffusion is thus sufficient to account for the segregation of the metal into the existing masses, without

need for appeal to a circulation of solutions or any specific cause for precipitation. The presence of chalcocite at some localities fits in as well with this theory as with any other; it is of course difficult to account for the origin of the sulphur, but surely the original igneous rocks contained sulphides of some sort, even original chalcocite being by no means excluded by failure to observe it in the few samples examined.

DESCRIPTION OF PROPERTIES.—The position of the various prospects is indicated on the accompanying sketch map, which is chiefly copied from that in U.S.G.S. Bulletin 136, with the few changes noted above. The majority have been started at the outcrop of one of the numerous epidote-bearing layers in the greenstone, which frequently show copper stains where exposed at the surface. The hope has evidently been that the percentage of metal would increase in depth, but this does not seem to have been realized, since the openings have mostly been allowed to fill with water and cave in. Assays indicating valuable deposits were frequently obtained, as recorded in the literature, but these appear to have been without exception made on picked specimens, and there is no record of anything like an adequate sampling of any of the ore bodies.

The Russell Mine, consisting of a large shaft 120 feet deep, is being kept pumped out by the Reed Hill Copper Company, although no actual work is going on. The same company has a drift extending some 100 feet northward into the hill, about a mile further south, but here also operations are suspended.

In the summer of 1907 the Virgin Copper Company began prospecting with diamond drill on property located by Mr. Charles E. Wills, of Fountaindale. The bed of epidote rock outcropping on the western slope of a small ridge was 8 inches thick, and dipped about 45 degrees eastward. The drilling indicated an increase in thickness in depth, and accordingly in the spring of 1908 a slope was begun above the point of outcrop, and has been driven downward in the soft chlorite schist overlying the epidote layer.

It has thus far been continued over 250 feet, and cross cuts have been driven back under the slope at the 150, 200, and 250 foot levels, all of them proving the continuity of the epidote bed without apparent decrease in copper content. The writer's estimates of the proportion of copper in the quartz-calcite vein

material, as exposed in the upper cross cut, gave 10 per cent., and as this vein material certainly makes up less than 10 per cent. of the epidote rock, the ore can hardly carry more than 1 per cent. of metal, an amount not workable at a profit. Should, however, the percentage of copper in the veins, or the proportional amount of them, increase in depth, a workable body might be obtained, and it was hoped that geological examination would throw some light on the probability of such an outcome.

Bearing in mind the probable manner of deposition of the metal discussed above, it will be seen that the first of these possibilities is excluded. Since the metal and the quartz were formed simultaneously and by the same processes, no change in their relative amounts is to be expected. On the other hand, it is quite possible for the proportion of vein material in the epidote rock to increase, since it is determined by the degree of shattering which the rock has undergone, and this would be greatest at the point of greatest deformation of the rocks of this particular area, which might equally well be 1000 feet down as at the present surface of the ground. There is, however, nothing about the distribution of the various rocks at the surface which can give any clue to this problem; the only way to decide it is by exploration such as is now being carried on. So all estimates as to the probable value of the property must be reserved until the behavior of the epidote layer with increasing depth can be determined.

The other mines in the region are less promising. The Eagle Metallic Copper Company started work in 1904 about a mile southeast of the locality just described, following a similar epidote layer over 300 feet at an inclination of 30°. After passing the oxidized zone the quartz veins were found to contain occasional small grains of chalcocite, and an abundance of specular hematite. No workable ore appears to have been obtained, and the slope is now full of water. A similar state of affairs was found to exist at the various other points indicated on the map, and it would seem that the future of the district depends largely on the results of the explorations of the Virgin Copper Company. In view of the commendable manner with which they are going about this work, and considering the interest which would attach to a working copper mine in so easily accessible a region in the eastern part of the country, they are certainly to be wished every success.

SUMMARY OF CONCLUSIONS.

The region is occupied by two pre-Cambrian effusive igneous rocks, a rhyolite and a basalt, both considerably altered. The latter was probably the first to form, the acid rock being in part in dikes cutting through it, and a contact exposed during recent mining operations showing a rhyolite lava overlying basalt. The deposits consist chiefly of native copper in quartz veins in epidotized layers in the basalt lava. It is believed that the metal was originally distributed throughout this rock and has been concentrated, like the associated quartz, by diffusion, in obedience to the principle that large crystals grow at the expense of small ones; that the copper was reduced by the ferrous iron of the rock constituents, and transported as a dilute solution of free metal; and that the association with epidote is of physical rather than of chemical significance, in that the epidotized layers were the only ones of sufficiently resistant character to permit of the development of open cracks during the regional metamorphism. The workability of the deposits depends upon the possible increase of these quartz veins in depth, but it seems impossible to predict this from surface indications, and extended exploration is thought to be the only way to settle the question as to the future of the district.

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Poles Purchased in 1909.—The total number of poles reported to the Bureau of the Census as purchased during the calendar year 1909 by the telegraph and telephone companies, steam and electric railroads, and electric light and power companies of the United States was 3,739,000, as against 3,249,000 in 1908 and 3,283,000 in 1907. There were purchased in 1909 by the same class of users 3,509,000 cross-arms, 6,168,000 brackets, and 18,463,000 insulator pins. Cross-arms, brackets, and insulator pins were not included in the annual census of lumber and timber products prior to 1909.

This information appears in a preliminary comparative report covering 1909, 1908, and 1907, which was transmitted to Census Director Durand by Chief Statistician William M. Steuart, under whose supervision it was prepared by J. E. Whelchel, expert special agent of the Division of Manufactures. In co-operation with the Forest Service of the Department of Agriculture, the Bureau of the Census annually collects and publishes statistics pertaining to the group of lumber and timber industries.

Telephone and telegraph companies reported purchases during 1909 of 2,916,000 poles, or 78 per cent. of the total. This was an increase over 1908 in the number reported as bought by this class of users of 354,000 poles, or 14 per cent., and over 1907 of 604,000 poles, or 26 per cent. Steam railroads reported the purchase of 26 per cent. more poles in 1909 than in 1908, though 34 per cent. less than in 1907, while the reported purchases by electric railroads and electric light and power companies were 18 per cent. greater than in 1908 and 7 per cent. less than in 1907.

There was little change in the average cost per pole of all lengths and from all species of wood in 1909, as compared with 1908, it being $1.89 in the later and $1.82 in the earlier year. The

average cost per pole, $2.46, in 1907, was substantially larger than in either of the later years, mainly for the reason that a class of pole consumers in the United States which uses chiefly short poles was not included in the census for 1907.

Cedar continues to be the principal pole timber, contributing 65 per cent. of the total purchases in 1909, 68 per cent. in 1908, and 64 per cent. in 1907. Chestnut, after cedar, was used in greatest quantity in all three years, forming 16 per cent. of the total in 1909, 16 per cent. in 1908, and 19 per cent. in 1907. Among the remaining species, the increase in the number of oak poles reported as purchased during the last three years is noteworthy; more than three times as many poles from this species have been reported as purchased during 1909 as was the case in 1907.

Substantial progress in the practice of treating poles with chemicals to preserve them from decay is disclosed by the re-turns for 1909, nearly one-sixth of the total purchases during that year having been given some preservative treatment, as against about one-tenth in 1908 and one-eighth in 1907.

Of the total outlay during 1909, $1,621,000, for cross-arms, brackets, and insulator pins, the telegraph and telephone com-panies contributed 63 per cent., electric railroads and electric light and power companies 32 per cent., and steam railroads 4 per cent.

The comparative summary follows:

THE SUMMARY OF POLES PURCHASED.

Kinds of Wood.	1909		1908		1907	
	Number.	Cost.	Number.	Cost.	Number.	Cost.
Cedar...............	2,440,000	4,680,000	2,200,000	3,781,000	2,109,000	5,203,000
Chestnut...........	608,000	1,383,000	516,000	1,227,000	630,000	1,620,000
Oak...............	237,000	137,000	161,000	95,000	76,000	60,000
Pine...............	180,000	520,000	117,000	383,000	156,000	460,000
Cypress.............	78,000	117,000	91,000	148,000	100,000	308,000
Juniper.............	44,000	79,000	42,000	83,000	39,000	109,000
Tamarack...........	30,000	18,000	24,000	32,000	14,000	10,000
Douglas fir..........	25,000	35,000	20,000	80,000	16,000	41,000
Redwood............	23,000	49,000	13,000	39,000	31,000	109,000
Bois d'Arc..........	21,000	9,000	18,000	11,000	6,000	3,000
Spruce.............	11,000	18,000	8,000	23,000	11,000	29,000
Locust.............	10,000	9,000	10,000	8,000	5,000	4,000
All other............	32,000	19,000	29,000	18,000	89,000	126,000
Total............	3,739,000	$7,074,000	3,249,000	$5,929,000	3,283,000	$8,082,000

Power House Economies. (*Iron Age,* lxxxvi, 15.)—The offer of $5000 as prizes in a competition between warships for showing economy, resulted in saving $1,000,000 in a year. The presumption is that the engineering staffs of the ships were ordinarily watchful of extravagance before the system of economy was inaugurated, yet it is evident there was much waste. This is suggestive of the possible economies in the power-houses of manufacturing plants.

PROPERTIES OF DRY, SATURATED AND UNSATURATED AIR; WITH APPLICATION TO COOLING-TOWER AND EVAPORATIVE SURFACE CONDENSER CALCULATIONS.

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Air is said to be saturated when it contains all the water vapor it can hold at the existing temperature without causing precipitation. If the air is only partially saturated it will tend to become saturated by absorbing moisture from surrounding objects. The drier the air the greater will be its affinity for moisture. The necessary heat to effect vaporization is supplied directly by the water producing the vapor or by the surrounding objects in contact with the water. Thus, in the open cooling tower the vapor is absorbed from the circulating water, and the heat necessary to cause this evaporation is given up by the circulating water itself; and in the evaporative surface condenser the vapor is absorbed from the water spray in contact with the tubes, the heat required to effect this vaporization being given up by the steam within the condenser proper, resulting in condensation of the steam. If the air is very dry and at a high temperature the vaporization of the water may be rapid enough to cool the remaining water to a temperature much lower than that of the air. In this case practically all of the cooling is affected by *evaporation*. But when the air is at a low temperature and nearly saturated a considerable amount of heat may be carried away by *conduction*. Except in the case of perfectly dry air, isolated from moisture in any form, the cooling process results in a loss of water, which for all practical purposes cannot be reclaimed. Atmospheric air is never dry and is seldom saturated even during a severe thunder shower.

If air is only partially saturated the ratio of the weight of water present to that required for complete saturation at the given temperature and pressure is called the *relative humidity*. The latter also represents the ratio of the existing vapor tension

to the maximum tension at the same temperature. The degree of saturation, or relative humidity, is ordinarily determined from the difference in reading of a wet and dry bulb thermometer, thus: If the air is completely saturated no evaporation takes place from the wet bulb and the two thermometers give identical readings; but if it is unsaturated, evaporation takes place, the wet bulb thermometer is cooled and its reading is lower than that of the dry bulb. The difference in reading is a function of the relative humidity and the latter may be obtained from "Hygrometric Tables" or calculated by means of the following modification of Apjohn's formula:

If the thermometer reads above 32° F.,

$$h = \left(P_w - \frac{dP}{2640} \right) \frac{100}{P_d}. \tag{1}$$

If the thermometer reads below 32° F.,

$$h = \left(P_w - \frac{dP}{2880} \right) \frac{100}{P_d}. \tag{2}$$

in which

h = relative humidity, per cent.;

d = difference in reading of the wet and dry thermometers, degrees F.;

P = barometric pressure, inches of mercury;

P_w = maximum tension of aqueous vapor corresponding to the temperature of the wet thermometer, inches of mercury (this may be obtained directly from Steam Tables);

P_d = maximum tension of aqueous vapor corresponding to the temperature of the dry thermometer, inches of mercury.

Example.—Determine the relative humidity when the dry bulb reads 80° F., wet bulb 60° F., barometer 29.5.

From Steam Tables:

$$P_w = 0.522 ; \quad P_d = 1.029 ;$$
$$h = \left(0.522 - \frac{(80-60)29.5}{2640} \right) \frac{100}{1.029} = 29 \text{ per cent.}$$

The design of condensers, dry kilns, cooling-towers and heating and ventilating apparatus is greatly facilitated by the use of "Saturated Air Tables." A convenient form is illustrated in Table I. The factors involved in this table are based upon the following fundamental physical laws:

Dalton's Laws.—(1) The mass of a given kind of vapor required to saturate a given space at a given temperature is the same whether the vapor is all by itself or associated with vaporless gases. (2) The maximum tension of a given kind of vapor at a given temperature is the same whether it is all by itself or associated with vaporless gases. (3) In a mixture of gas and vapor the total pressure is equal to the sum of the partial pressures.

These laws may be expressed:

For saturated air

$$P = P_1 + P_v \tag{3}$$
$$d = d_1 + d_v \tag{4}$$

For unsaturated air

$$P = P_1 + hP_v \tag{5}$$
$$d = d_1 + hd_v \tag{6}$$

in which

$P =$ observed atmospheric pressure as obtained from the barometer;

$P_1 =$ pressure of the dry air in the mixture;

$P_v =$ pressure of the vapor in the mixture. (This may be taken from Steam Tables. It is the pressure of the steam at the temperature corresponding to that of the mixture of air and vapor.)

$d =$ density or weight per cubic foot of the mixture at a given P and t;

$d_1 =$ density of dry air at pressure P_1 and temperature t;

$d_v =$ density of vapor at pressure P_v and temperature t. (This may be taken directly from Steam Tables.)

Densities, pressures and temperatures are conveniently taken in pounds, inches of mercury absolute, and degrees Fahrenheit, respectively.

Charles's Law.—All gases expand equally when heated at constant pressures and for every degree Fahrenheit the amount of expansion is $\frac{1}{459.6}$ of the volume occupied at $0°$ F., or $\frac{1}{459.6 + t}$ of the volume occupied at any temperature "t." For most purposes this may be taken as $\frac{1}{460 + t}$.

For unsaturated water vapor the law is approximately true, the deviation being greatest as the saturation point is approached.

TABLE I.—PROPERTIES OF

MIXTURE OF AIR SATURATED

Temperature, degrees F.	Weight of 1000 cu. ft. of dry air, pounds	Volume of one lb. of dry air, cu. ft.	Elastic force of vapor, inches of mercury (Marks & Davis)	Elastic force of the dry air in the mixture, inches of mercury	Weight of 1000 cu. ft., pounds		
					Weight of the dry air, content	Weight of the vapor, content	Total weight of the mixture
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
0	86.35	11.58	*0.044	29.88	86.23	0.081	86.31
10	84.51	11.83	*0.069	29.85	84.31	0.125	84.43
20	82.75	12.08	*0.107	29.81	82.44	0.189	82.63
30	81.06	12.33	*0.156	29.76	80.62	0.273	80.89
32	80.73	12.39	0.180	29.74	80.24	0.304	80.54
35	80.24	12.46	0.203	29.72	79.70	0.340	80.04
40	79.43	12.59	0.248	29.67	78.77	0.410	79.18
45	78.64	12.72	0.300	29.62	77.86	0.492	78.35
50	77.88	12.84	0.362	29.56	76.94	0.587	77.53
55	77.12	12.97	0.436	29.48	75.98	0.700	76.68
60	76.38	13.09	0.522	29.40	75.05	0.828	75.88
62	76.08	13.14	0.560	29.36	74.66	0.885	75.54
65	75.65	13.22	0.622	29.30	74.08	0.977	75.06
70	74.94	13.34	0.739	29.18	73.08	1.15	74.23
72	74.65	13.40	0.790	29.13	72.68	1.22	73.90
75	74.24	13.47	0.873	29.05	72.08	1.35	73.42
80	73.55	13.60	1.03	28.89	71.01	1.57	72.58
85	72.87	13.72	1.21	28.71	69.92	1.83	71.75
90	72.21	13.85	1.42	28.50	68.78	2.13	70.91
95	71.56	13.97	1.66	28.26	67.59	2.47	70.06
100	70.92	14.10	1.93	27.99	66.34	2.85	69.19
105	70.29	14.23	2.24	27.69	65.05	3.28	68.33
110	69.67	14.35	2.59	27.33	63.64	3.77	67.41
115	69.07	14.48	2.99	26.93	62.16	4.31	66.47
120	68.47	14.61	3.44	26.48	60.60	4.92	65.52
125	67.88	14.73	3.95	25.97	58.92	5.61	64.53
130	67.31	14.86	4.52	25.40	57.14	6.37	63.51
135	66.74	14.98	5.16	24.76	55.23	7.21	62.44
140	66.19	15.11	5.88	24.04	53.18	8.14	61.32
145	65.64	15.23	6.67	23.25	51.01	9.18	60.19
150	65.10	15.36	7.57	22.35	48.63	10.32	58.95
155	64.57	15.49	8.55	21.37	46.12	11.57	57.69
160	64.05	15.61	9.65	20.27	43.39	12.96	56.35
165	63.54	15.74	10.86	19.06	40.47	14.48	54.95
170	63.04	15.86	12.20	17.72	37.33	16.14	53.47
175	62.54	15.99	13.67	16.25	33.96	17.96	51.92
180	62.05	16.12	15.29	14.63	30.34	19.94	50.28
185	61.57	16.24	17.07	12.85	26.44	22.10	48.54
190	61.09	16.38	19.02	10.90	22.26	24.44	46.70
195	60.63	16.50	21.15	8.77	17.17	27.00	44.77
200	60.17	16.62	23.47	6.45	12.97	29.76	42.73
205	59.71	16.74	26.00	3.92	7.82	32.76	40.58
210	59.27	16.86	28.76	1.16	2.30	35.97	38.27
212	59.09	16.92	29.92	0	0	37.32	37.32

* Regnault.

SATURATED AIR. (BAROMETER 29.921.)

WITH WATER VAPOR

Ratio of dry air to water vapor	Weight of water necessary to saturate 100 lbs. of dry air	Cu. ft. of vapor from one lb. of water at pressure, as in column 4	B.T.U. absorbed by 1000 cu. ft. of dry air per degree F.	B.T.U. absorbed by 1000 cu. ft. of saturated air per degree F.	Cu. ft. of dry air warmed one degree F., per B.T.U.	Cu. ft. of saturated air warmed one degree F., per B.T.U.	Temperature, degrees F.
9	10	11	12	13	14	15	16
1064.0	0.094	. . . . . .	20.51	20.52	48.75	48.74	0
674.0	0.148	. . . . . .	20.07	20.08	49.80	49.79	10
436.0	0.229	. . . . . .	19.65	19.67	50.89	50.84	20
295.0	0.338	. . . . . .	19.25	19.27	51.94	51.89	30
264.0	0.379	3294.0	19.17	19.19	52.16	52.11	32
234.0	0.468	2938.0	19.06	19.08	52.47	52.41	35
192.0	0.521	2438.0	18.86	18.89	53.02	52.94	40
159.0	0.632	2038.0	18.68	18.72	53.53	53.42	45
131.0	0.763	1702.0	18.49	18.54	54.04	53.94	50
108.0	0.921	1430.0	18.31	18.37	54.61	54.43	55
91.0	1.10	1208.0	18.14	18.20	55.12	54.94	60
85.0	1.18	1130.0	18.07	18.13	55.33	55.16	62
76.0	1.32	1024.0	17.96	18.03	55.68	35.53	65
64.0	1.57	871.0	17.80	17.88	56.18	55.93	70
59.0	1.68	817.0	17.74	17.82	56.36	56.12	72
54.0	1.87	743.0	17.63	17.74	56.71	56.37	75
45.0	2.21	637.0	17.47	17.59	57.23	56.85	80
38.0	2.62	546.0	17.31	17.45	57.77	57.30	85
32.0	3.08	469.0	17.14	17.31	58.34	57.77	90
27.0	3.65	405.0	17.00	17.20	58.82	58.14	95
23.0	4.29	351.0	16.84	17.06	59.38	58.62	100
20.0	5.04	305.0	16.69	16.96	59.92	58.96	105
17.0	5.92	266.0	16.54	16.85	60.46	59.35	110
14.0	6.93	232.0	16.40	16.74	60.97	59.74	115
12.0	8.12	203.0	16.26	16.65	61.50	60.06	120
11.0	9.46	178.0	16.12	16.57	62.03	60.35	125
9.0	11.20	157.0	15.98	16.50	62.58	60.61	130
7.7	12.90	139.0	15.85	16.41	63.09	60.93	135
6.5	15.30	123.0	15.72	16.37	63.61	61.08	140
5.5	17.90	109.0	15.59	16.33	64.14	61.23	145
4.7	21.70	96.9	15.46	16.29	64.68	61.38	150
4.0	25.10	86.4	15.33	16.27	65.23	61.46	155
3.3	29.90	77.2	15.21	16.26	65.75	61.50	160
2.8	35.80	69.1	15.09	16.27	66.27	61.46	165
2.3	43.20	62.0	14.97	16.29	66.80	61.38	170
1.9	54.80	55.7	14.85	16.33	67.34	61.23	175
1.5	65.70	50.1	14.74	16.38	67.84	61.05	180
1.2	83.80	45.2	14.62	16.44	68.40	60.83	185
0.91	111.0	40.9	14.51	16.53	68.92	60.49	190
0.66	191.0	37.0	14.40	16.64	69.44	60.96	195
0.44	229.0	33.6	14.29	16.77	69.98	59.63	200
0.24	419.0	30.5	14.18	16.92	70.52	59.10	205
0.06	. . . . .	27.8	14.07	17.09	71.07	58.58	210
0	. . . . .	26.8	14.03	17.16	71.33	58.27	212

For saturated water vapor the law is not applicable and recourse must be had to Steam Tables.

This law may be expressed:

$$V_1 = V \times \frac{t_1 + 460}{t + 460}; \tag{7}$$

$$d_1 = d \times \frac{t + 460}{t_1 + 460}; \tag{8}$$

in which

$V_1 =$ volume of gas at temperature t_1 and constant pressure;
$V =$ volume of gas at temperature t and constant pressure;
$d_1 =$ density of gas at temperature t_1 and constant pressure;
$d =$ density of gas at temperature t and constant pressure.

Boyle's Laws.—The volume occupied by a given mass of gas under different pressures is inversely proportional to the pressure provided the temperature remains constant.

For unsaturated water vapor the law is approximately true, the deviation increasing as the saturation point is reached.

For saturated water vapor this law is not applicable and recourse must be had to Steam Tables.

This law may be expressed:

$$PV = P_1 V_1 \tag{9}$$

$$Pd_1 = P_1 d \tag{10}$$

(Notations as above.)

Laws of Charles and Boyle Combined.—When pressure and temperature both change, we have

$$V = V_1 \frac{P_1(t + 460)}{P(t_1 + 460)}; \tag{11}$$

$$d = d_1 \frac{P(t_1 + 460)}{P_1(t + 460)}. \tag{12}$$

Practically all the problems involving the use of gases, dry, saturated or partially saturated, may be conveniently solved by means of equations (1) to (12).

The different items in Table I will be calculated in order to show the application of the various physical laws.

Standard atmospheric pressure is taken as 29.921 inches of mercury or 14.7 pounds per square inch and all steam and air tables are based upon it. We will assume that Steam Tables

are available and that the density of air at $0°$ F., pressure 29.921, is known, or $d = 0.08635$.

Let us determine the various properties corresponding to, say, a temperature of 100° F., and standard atmospheric pressure.

Column 2.

From equation (8)

$$d_1 = d\left(\frac{t + 460}{t_1 + 460}\right)$$
$$= 0.08635\left(\frac{0 + 460}{100 + 460}\right)$$
$$= 0.07092 = \text{density of one cubic foot of } dry \text{ air under the required conditions.}$$

The various items in the column have been multiplied by 1000 to avoid unwieldly decimals.

Column 3.

The figure in this column is the reciprocal of the density of one cubic foot at 100° F., thus:

$$V_1 = \frac{1}{d_1} = \frac{1}{0.07092}$$
$$= 14.1 = \text{cubic feet per pound of dry air under the required conditions.}$$

Column 4.

The figure in this column is taken directly from the Steam Tables.

Column 5.

From equation (3)

$$P = P_1 + P_v$$
$$29.921 = P_1 + 1.93$$

From which

$P_1 = 27.99 = $ tension or elastic force of the dry air in the mixture.

Column 6.

From equation (9)

$$Pd_1 = P_1 d$$
$$29.921 \ d_1 = 27.99 \times 0.07092$$

or, $d_1 = 0.06634 = $ weight of dry air in one cubic foot of the saturated mixture. Weight of 1000 cubic feet $= 66.34$ pounds.

Column 7.

From Steam Tables we find the density of one cubic foot of water vapor at 100° F., to be

$$d_v = 0.00285 \text{ lbs.}$$
The weight of 1000 cubic feet $= 2.85$ lbs.

<div align="center">Column 8.</div>

From equation (5)

$$d = d_v + d_1$$
$$= 0.00285 + 0.06634$$
$$= 0.06919 = \text{weight of one cubic foot of the saturated mixture.}$$

Weight of 1000 cubic feet $= 69.19$ lbs.

<div align="center">Column 9.</div>

$\dfrac{d_1}{d_v} = \dfrac{0.06634}{0.00285} = 23 =$ ratio of dry air to water vapor in a saturated mixture.

<div align="center">Column 10.</div>

$\dfrac{d_v}{d_1} = \dfrac{0.00285}{0.06634} = 0.0429 =$ ratio of water vapor to dry air or the weight of vapor necessary to saturate one pound of dry air.

Vapor required to saturate 100 pounds of dry air $= 4.29$ lbs.

<div align="center">Column 11.</div>

This is the specific volume of saturated steam at the given temperature and may be obtained directly from the Steam Tables.

<div align="center">Column 12.</div>

B.T.U. absorbed $=$ weight of 1000 cubic feet of dry air times specific heat.
B.T.U. $= 70.92$ (column 2) times $0.2375 = 16.84$.

<div align="center">Column 13.</div>

1000 cubic feet of mixture at 100° F., contains 66.34 pounds of dry air (column 6) and 2.85 pounds of water vapor (column 7).

B.T.U. absorbed by the dry air $= 66.34 \times 0.2375 = 15.76$
B.T.U. absorbed by the vapor $\quad = 2.85 \times 0.46 \quad = 1.30$
———
B.T.U. absorbed by the saturated mixture $\quad = 17.06$

0.46 is taken as the specific heat of water vapor under the given conditions.

Columns 14 and 15 are reciprocals of the B.T.U. absorbed per pound of dry and saturated air, respectively.

<div align="center">PRACTICAL APPLICATION.</div>

Closed Cooling-Tower.—Determine the quantity of air and "make up water" necessary to cool 10000 pounds of water per hour from 120 to 80° F., with operating conditions as follows: Temperature of the air entering and leaving the tower,

70 and 110° F., respectively; relative humidity of the air entering and leaving the tower 70 and 95 per cent. respectively; barometric pressure 29.52 inches.

The heat H_t to be withdrawn in order to cool 10000 pounds of water per hour from 120 to 80° F., is

$$Ht = 10000 \ (120 - 80) = 400,000 \ \text{B.T.U.}$$

Neglecting radiation, leakage and other minor losses this heat is dissipated (1) in raising the temperature of the entering air and its vapor content from 70 to 110° F., and (2) in evaporating the moisture absorbed by the air in passing through the tower.

Heat Absorbed by the Dry Air.—The pressure of the dry air in the atmospheric air entering the cooling tower, is (equation 5)

$$\begin{aligned} P_1 &= P - hP_v \\ &= 29.52 - 0.7 \times 0.74 \\ &= 29.0. \end{aligned}$$

Similarly the pressure of the dry air leaving the tower is

$$\begin{aligned} P_2 &= 29.52 - 0.95 \times 2.591 \\ &= 27.06. \end{aligned}$$

If $V =$ column of atmospheric air in thousands of cubic feet entering the tower, its volume will be increased to $1.15 \ V$ on leaving the tower because of the increase in temperature and decrease in pressure, thus (equation 11)

$$V_1 = \frac{29}{27.06} \times \frac{460 + 110}{460 + 70} = 1.15 \ V.$$

The weight of w' of dry air entering the cooling tower is

$$\begin{aligned} w' &= d\frac{P_1}{P}V \\[2mm] &= 74.94 \ \frac{29.0}{29.92} \ V \\[2mm] &= 72.7 V \ \text{lbs.} \quad (74.94 = \text{density of 1000 cu. ft.} \\ & \qquad \text{of dry air at 70° F., and 29.92 inches pres-} \\ & \qquad \text{sure. See column 2, Table I.)} \end{aligned}$$

The heat H' required to heat w' lbs. of dry air from 70 to 110° is

$$H' = 0.24 \; w \; (110-70)$$
$$= 0.24 \times 72.7 \; V \times 40$$
$$= 698 \; V \text{ B.T.U.}$$

The weight w_0 of vapor carried into the tower with the air is

$w_0 = 0.70 \times 1.15 \; V$
   $= 0.805 \; V$ lbs. (0.70 = relative humidity and 1.15 = weight of
                        water vapor in 1000 cu. ft. of saturated air
                        at 70° F. See column 7 ,Table I.)

The heat H_0 required to superheat w_0 lbs. of vapor from 70° to 110° F., is

$$H_0 = w_0 \times 0.46 \; (110-70)$$
$$= 0.805 \; V \times 0.46 \times 40$$
$$= 14.8 \; V \text{ B.T.U.}$$

The weight w of vapor discharged from the top of the tower is

$w' = 1.15 V \times 0.95 \times 3.77$
   $= 4.119 V$ lbs. (1.15 V = volume of air discharged from the top
                      of the tower; 0.95 = its relative humidity; 3.77
                      = weight of water vapor in 1000 cu. ft. of satur-
                      ated air at 110° F.)

The amount evaporated, w, or the " make up water " is

$$w = w_1 - w_0$$
$$= 4.119 \; V - 0.805 \; V$$
$$= 3.31 \; V \text{ lbs.}$$

The heat H required to evaporate w lbs. of water at 110° F. is

$$H = 1030 \; w$$
$$= 1030 \times 3.31 \; V$$
$$= 3409 \; V.$$

The total heat H_t absorbed by the air and its vapor content in passing through the tower is

$$H_t = H_0 + H + H'$$
$$= 14.8 \; V + 3409 \; V + 698 \; V$$
$$= 4122 \, V.$$

But this represents also the heat abstracted from the circulating water, or

$4122 = V400,000$

$V = 97.0$ thousands of cubic feet of atmospheric air necessary to cool one thousand pounds of water under the given conditions.

The water evaporated or the " make up water " is

$$w = 3.31 \ V$$
$$= 3.42 \times 97$$
$$= 321 \text{ pounds.}$$

The per cent. of circulating water lost by evaporation is

$$100 \frac{321}{10,000} = 3.2.$$

Evaporative Surface Condenser.—How many cubic feet of air and how many pounds of water spray must be forced through an evaporative surface condenser of the fan type in order to condense 1000 pounds of steam per hour and maintain a vacuum of 24.5 inches, barometer 29.5 (atmospheric air 80° F., relative humidity 70 per cent.) ; air and vapor issuing from the discharge pipe under pressure of four inches of water, temperature 125° F., relative humidity 98 per cent.?

The absolute pressure in the condenser is

$$29.5 - 24.5 = 5 \text{ inches of mercury.}$$

The total heat to be withdrawn in order to condense 1000 pounds of steam per hour at absolute pressure of 5 inches is

$1000 \times 1020.8 = 1,020,800$ B.T.U.

(1020.8 being the latent heat of vaporization at this pressure.)

Neglecting radiation and leakage losses, this is the heat to be abstracted per hour by the air and water spray.

The pressure of the dry air in the mixture entering the condenser is

$$P_1 = 29.5 - 0.7 \times 1.029$$
$$= 28.78.$$

The pressure of the dry air in the mixture leaving the condenser is

$$P_2 = (29.5 + 0.294) - 0.98 \text{ x } 3.95$$
$$= 25.92. \text{ (0.294 is the fan pressure in inches of mercury.)}$$

The volume of air V_1 leaving the condenser will be greater than the volume V (thousands of cu. ft. per hour) entering on account of the reduction in pressure and the increase in temperature, thus:

$$V_1 = \frac{28.78}{25.92} \text{ x } \frac{460 + 125}{460 + 70} V$$
$$= 1.22 V.$$

The weight of vapor w_0 brought in with the atmospheric air is

$$w_0 = 0.7 \text{ x } 1.57 \ V$$
$$= 1.1 \ V \text{ lbs.}$$

The weight of vapor w_1 in the discharge is

$$w = 1.22 \ V \text{ x } 5.61 \text{ x } 0.98$$
$$= 6.58 \text{ lbs.}$$

The amount evaporated is

$$w = w_1 - w_0$$
$$= 6.58 \ V - 1.1 \ V$$
$$= 5.48 \ V \text{ lbs.}$$

The heat H_0 required to superheat w_0 lbs. of water vapor from 80° to 125° F., is

$$H_0 = 0.46 \text{ x } w_0 \ (125 - 80)$$
$$= 0.46 \text{ x } 1.1 V \text{ x } 45$$
$$= 22.8 \ V \text{ B.T.U.}$$

The heat H required to evaporate w lbs. of water at 125° F.,

$$H = 1027.1 \ w$$
$$= 1027.1 \text{ x } 5.48 \ V$$
$$= 5628.1 \ V.$$

The weight of dry air, w, entering the condenser is

$$w = \frac{28.78}{29.92} \text{ x } 73.55 V = 70.8 V.$$

The heat H' required to raise the temperature of w' pounds of dry air from 80° to 125° is

$$H' = 0.24 \, w \ (125 - 80)$$
$$= 0.24 \times 70.8 \ V \times 45$$
$$= 764.6 \ V.$$

The total H_t absorbed by the entering air and spray is

$$H_t = H_0 + H + H'$$
$$= 22.8 \ V + 5628.1 + 764.6 \ V$$
$$= 6410.5 \ V.$$

But this represents also the heat given up by the steam, or

$$6410.5 \ V = 1,020,800.$$

From which

$V = 159.6$ thousands of cubic feet of atmospheric air necessary to condense 1000 pounds of steam under the required condition.

The weight of water spray, w, to be injected per hour is

$$w = 5.48V$$
$$= 5.48 \times 159.6$$
$$= 874.6 \text{ pounds.}$$

$\dfrac{H}{H_1} = \dfrac{5628.1 V}{764.6 V} = 7.4$, that is, the water spray absorbs 7.4 more heat than the dry air under the given conditions.

Production of Tungsten in 1910.—*Largest Recorded Production.*—Owing to a stronger demand, the price for tungsten ores was higher in 1910 than 1909, and the production therefore rose. The output as calculated from returns received directly from producers and mill men was the largest so far made in this country —1824 short tons, valued at $832,992. Prospecting and development, which have been proceeding more or less steadily in an increasing ratio for the past seven or eight years, have found new deposits and opened known ones, so that there is now a fairly ready response to market demands. The Boulder County, Colorado, field is still the largest producing section, and the Atolia, California, field is second. The ore mined in Boulder County is ferberite (iron tungstate). The Atolia tungsten ore is scheelite. The Atolia field is much smaller than the Boulder field, and gives a higher yield proportionate to area. Returns of 1221 short tons of ore

carrying 60 per cent. tungsten trioxide have been made by Boulder County buyers and producers.

The production of 1910 is believed to be the largest annual output made by this or any other country to date, but the value is less than that of the output for 1907, which was 1640 short tons, valued at $890,048. Very high prices prevailed during 1907 and tungsten at one time during that year reached a price of $14 per unit (1 per cent. of a ton in tungsten trioxide). During 1910 prices ranged from $6.50 to $8.50 per unit for ore carrying 60 per cent. or more of tungsten trioxide. Leaner ores brought a lower price per unit. A little ore was sold as high as $9 or more per unit to buyers having special needs.

The production of concentrated tungsten ores in the United States since 1900 has been as follows:

PRODUCTION OF TUNGSTEN CONCENTRATES IN THE UNITED STATES, 1900–1910, IN SHORT TONS.

Year.	Quantity.	Value.	Year.	Quantity.	Value.
1900	46	$11,040	1906	928	348,867
1901	179	27,720	1907	1,640	890,048
1902	184	34,040	1908	671	229,955
1903	292	43,639	1909	1,619	614,370
1904	740	184,000	1910	1,824	832,992
1905	803	268,676			

The figures in this table can fairly be compared only since the beginning of 1906, as before that date no effort was made to reduce the ores to a common basis of concentration. Since 1906 the figures have been, as far as possible, made to represent the equivalent of ores carrying 60 per cent. tungsten trioxide, which is the ordinary commercial basis in the United States.

No tungsten ore was produced from other parts of Colorado than the Boulder field, although some efforts have been made to exploit the deposits near Silverton. In California, besides the large production made at Atolia, a small quantity of mixed wolframite and scheelite was mined near Nipton. In Arizona a small quantity of ore was produced from old fields, and efforts at production are being made anew near Oracle. In Washington some output of wolframite and hübnerite was made from three mines in Stevens County near Deer Trail, Deer Park, and Loon Lake, and several companies started work on other deposits in Stevens County. In Nevada a small output was made at Browns, Humboldt County. Considerable development work was done on the hübnerite deposits near Osceola, and a mill was put up for concentrating the ore, but no shipments were made during the year. Discoveries of hübnerite-bearing veins northeast of Osceola, near the Utah line (some of them are said to be in Utah), and at Redlich, Nevada, were reported during the year.

RECENT PROGRESS IN THE CHEMISTRY OF THE TERPENES AND CAMPHORS.

BY

JOSEPH SAMUEL HEPBURN, A.M., M.S.,

Secretary of the Section.

DURING the last quarter of a century, two great researches in the field of organic chemistry have been carried out in Germany, the one research in the aliphatic series upon carbohydrates, proteins and purin bases by Emil Fischer of the University of Berlin, the other research in the carbocyclic series upon the terpenes and camphors and their related compounds by Otto Wallach, the successor of the immortal Wöhler in the chair of chemistry at the University of Göttingen. Reviews of Fischer's work have recently appeared.[1] It is the purpose of this paper to give a resumé of Wallach's studies of the terpenes, camphors and other hydroaromatic compounds. These studies are embodied in over one hundred and fifty papers, published in the *Berichte der deutschen chemischen Gesellschaft*, Liebig's *Annalen der Chemie*, and the *Nachrichten der königlichen Gesellschaft der Wissenschaften in Göttingen, Mathematisch-physikalische Klasse* and have served as the source of Wallach's recent book "Terpene und Campher"[2] upon which this paper is chiefly based.

The labors of Wallach have not been limited to the terpenes and camphors but have extended to many related compounds, including *inter alia* the addition compounds of the terpenes, amines, pyrazols, alcohols, oxides, ketones, aldehydes, acids (mono- and dicarboxylic, amino, hydroxy, ketonic and halogenated). The work of Wallach was rendered exceed-

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[1] Recent Progress in the Chemistry of the Proteins, Bradbury, Journal of the Franklin Institute, 1909, clxviii, 85. Recent Progress in the Chemistry of the Sugars, Hepburn, Journal of the Franklin Institute, 1910, clxx, 85.

[2] Terpene und Campher. Zusammenfassung eiginer Untersuchungen auf dem Gebiet der alicyclischen Kohlenstoffverbindungen von Otto Wallach. Leipzig. Verlag von Viet & Comp, 1909.

ingly difficult by the lack of known compounds which would serve for the separation and identification of the individual terpenes, and by the tendency of the terpenes to become inverted, *i.e.*, to pass into metameric compounds under the influence of acids, alkalies, and heat. However, addition compounds of the terpenes were discovered which were suitable for the identification of the individual hydrocarbons, and the inversions of the terpenes were also investigated. The structure of the molecule was determined for the terpenes and their related compounds. Thus the difficulties were overcome and order was brought out of chaos.

The compounds which possess the empirical formula C_5H_8 fall into several classes:

C_5H_8—Hemiterpenes;

$C_{10}H_{16}$—Terpenes (True Terpenes);

$C_{15}H_{24}$—Sesquiterpenes;

$(C_{10}H_{16})_x$—Polyterpenes (Di-, Tri- and Tetraterpenes).

Isoprene is a hemiterpene, obtained by the destructive distillation of caoutchouc; it is methyl divinyl:

$$CH_2 = \overset{\overset{\displaystyle CH_3}{|}}{C} - CH = CH_2.$$
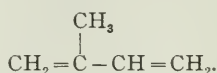
THE TERPENES.

The terpenes are hydro-aromatic hydrocarbons, closely related to cymol (methylisopropylbenzol). Every terpene contains a hydrogenated benzol nucleus and either a methyl and an isopropyl group, or radicals derived from these groups. The general formula of the terpenes is $C_{10}H_{16}$; their isomerism is dependent upon the position of double bonds and of the alkyl groups, and upon intracyclic bonds and intracyclic rings or bridges. The double or ethlyene bond may occur in the nucleus, in the side chain, or at the junction of the nucleus and the side chain. A double bond uniting nucleus and side chain is termed a semicyclic ethylene bond, and the compound, in which it occurs, is called a methene compound. Since two alkyl groups have been substituted in the nucleus of a terpene, it follows that these groups may be in either the ortho, meta or para position to each other. Certain terpenes contain an intracyclic bond which extends across
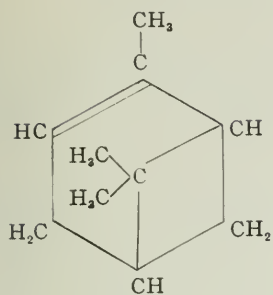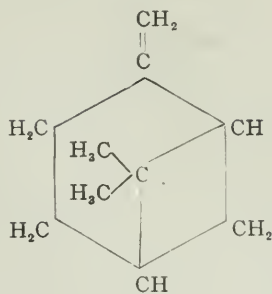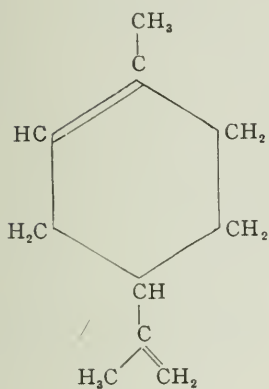
α-Pinene

β-Pinene

Limonene and Dipentene

Terpinolene

α-Terpinene

β-Terpinene

CH$_3$
C
HC
CH
H$_2$C
CH
CH
CH
H$_3$C
CH$_3$

a-Phellandrene

CH$_2$
C
H$_2$C
CH
H$_2$C
CH
CH
CH
H$_3$C
CH$_3$

β-Phellandrene

CH$_3$
C
HC
CH$_2$
H$_2$C
CH—C
CH$_2$
CH$_3$
CH$_2$

Sylvestrene

CH$_2$
C
HC
CH$_2$
H$_2$C
CH$_2$
C
CH
H$_3$C
CH$_3$

Sabinene

CH
H$_2$C
C=CH$_2$
H$_3$C—C—CH$_3$
H$_2$C
CH$_2$
CH

D-l-Fenchene

CH$_3$
C
H$_2$C
CH
H$_3$C—C—CH$_3$
H$_2$C
CH
CH
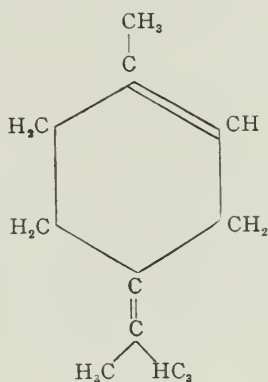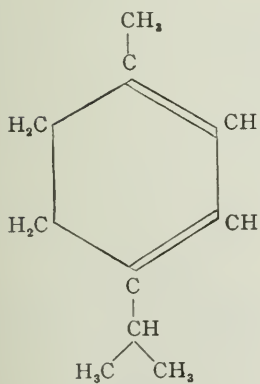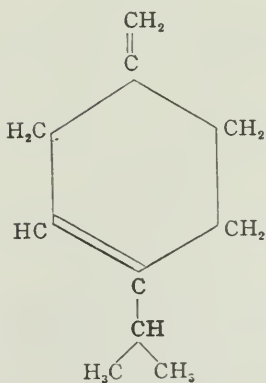
Camphene
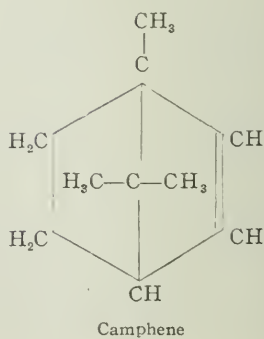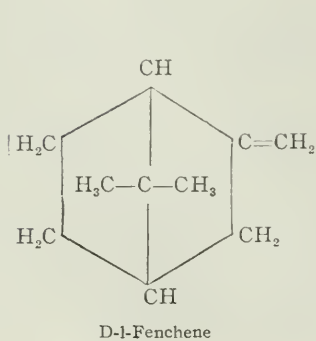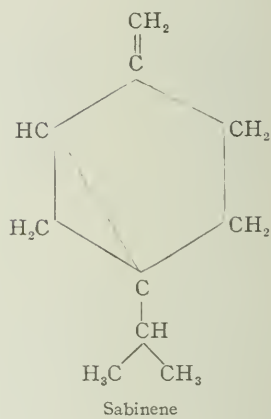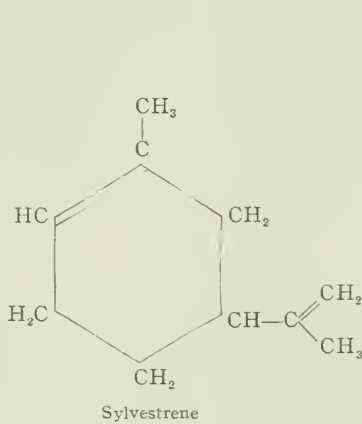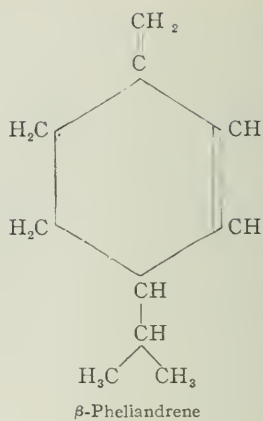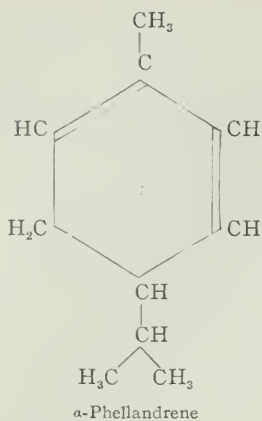
the nucleus linking two non-adjacent carbon atoms. Intra-cyclic rings or bridges are formed by a group

$$\overset{|}{\underset{|}{C}}(CH_3)_2$$

linked to two carbon atoms of the nucleus which are in either the meta or para position to each other.

Double bonds in the nucleus occur in d- and l-a-pinene, d- and l-limonene, dipentene, terpinolene, a- and β-terpinene, d- and l-a-phellandrene, β-phellandrene and sylvestrene; in fact a-terpinene and a-phellandrene are true dihydrocymols. Double bonds in the side chain are found in d- and l-limonene, dipentene and sylvestrene. Semicyclic double bonds, at the junction of nucleus and side chain, occur in β-pinene, ter-pinolene, β-terpinene, β-phellandrene and sabinene. Usually the substituent groups are attached to the nucleus in the para position to each other, e.g., limonene, terpinolene, phellandrene; however, these groups are in the meta position to each other in sylvestrene. A terpene of the ortho series has been obtained from the cyclic ketone ortho- or pseudo-pulegon; the ketone is reduced to the corresponding alcohol which loses water, when heated with phosphoric oxide, and passes into the ortho-terpene.
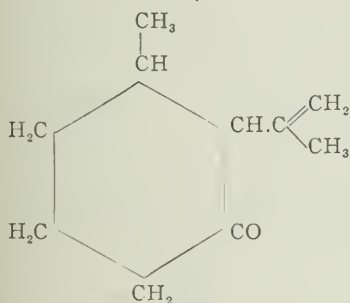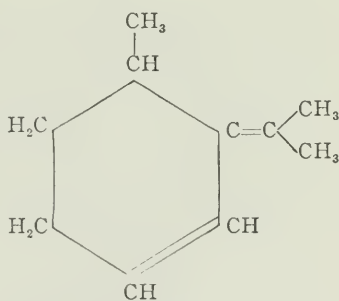
Ortho- or Pseudopulegon   Ortho-Terpene

An intracyclic bond is present in sabinene. An intracyclic ring or bridge, linked to two carbon atoms of the nucleus in the meta position to each other, is present in a- and β-pinene. A bridge uniting two carbon atoms of the nucleus in the para position to each other is found in fenchene and camphene.

The terpenes may be divided into three classes, natural terpenes, terpenes obtained by inversion of natural terpenes, and synthetic terpenes. The natural terpenes occur in various essential oils; Table I enumerates the natural terpenes and certain oils in which they occur.

TABLE I.

Terpene.	Essential Oil.
d-a-Pinene	American Turpentine Oil.
l-a-Pinene	French Turpentine Oil.
β-Pinene	Turpentine Oil.
d-Limonene	Oil of Lemon.
l-Limonene	Oil of Pinus Silvestris.
dl-Limonene (Dipentene)	Swedish and Russian Turpentine Oil, Camphor Oil.
a-Terpinene	Ceylon Cardamom Oil.
d-a-Phellandrene	Oil of Bitter Fennel.
l-a-Phellandrene	Oil of Eucalyptus Amygdalina.
β-Phellandrene	Oil of Water Fennel.
Sabinene	Ceylon Cardamom Oil.
Sylvestrene	Swedish and Russian Turpentine Oil.

Terpinolene is a terpene, obtained by inverting pinene by means of sulphuric acid. β-Terpinene is a synthetic terpene built up from sabina ketone. Sabina ketone $C_9H_{14}O$

Sabinaketone
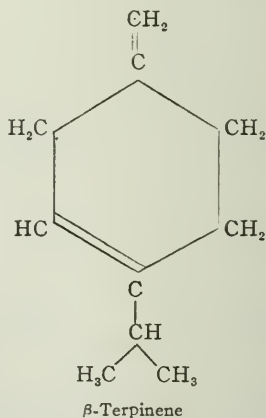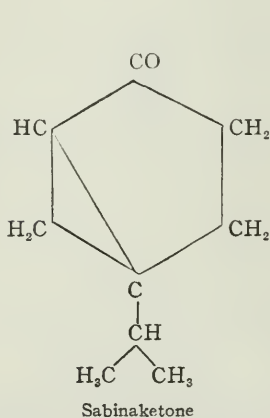
β-Terpinene

reacts with bromacetic ester, in the presence of zinc, to form an unsaturated acid C_9H_{14} : CH.COOH, which loses carbon dioxide to form β-terpinene, $C_{10}H_{16}$.

INVERSION.

Inversion is the term used to designate the phenomenon in which terpenes and their derivatives pass into isomeric compounds; the change depends on the rearrangement of the atoms in the molecule and a shifting of linkages. Inversion

Pulegon

Isopulegon

Isopulegon Oxime
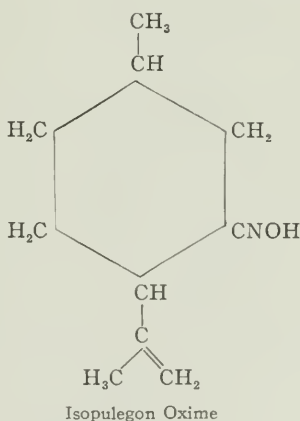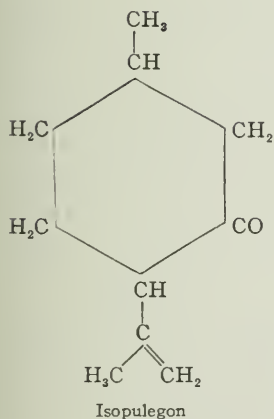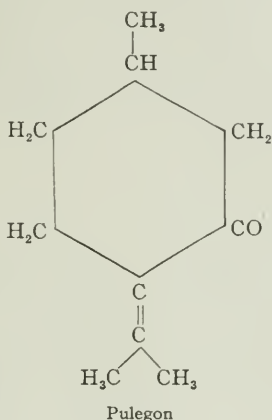
is produced by the action of acids or alkalies or by exposure to a somewhat elevated temperature. Thus under the influence of alcoholic-sulphuric acid, a-pinene and dipentene give rise to a-terpinene. At a temperature of 250–270°C., a-pinene

passes into dipentene. When the cyclic ketone pulegon is digested with an excess of hydroxylamine in the presence of much free alkali, the oxime of isopulegon is obtained; the alkali inverts pulegon into isopulegon, by shifting the semi-cyclic double bond into the side chain, during the formation of the oxime.

Terebene [3] of the Pharmacopœia consists of dipentene and other hydrocarbons; it is obtained by the action of con-centrated sulphuric acid on oil of turpentine, the pinene of the latter is inverted by the acid during the process of manu-facture and an optically inactive product is formed.

ADDITION PRODUCTS OF THE TERPENES.

The terpenes and certain of their derivatives are char-acterized by their ability to form addition products with halogens, haloid acids, nitrosyl chloride, nitrous anhydride, nitrogen peroxide, water, hydrogen sulphide and hydroxyl-amine. These addition products are of value in the separation and identification of the terpenes. The addition usually occurs at the double bonds, although it may also take place with an opening of intracyclic bonds or intracyclic bridges. The manner in which the addition takes place is illustrated by the following examples. Limonene adds dry hydrogen chloride at one of the double bonds to form optically active limonene monohydrochloride; in the presence of moisture, addition of haloid acid occurs at both double bonds with the formation of racemic dipentene dihydrochloride, inversion has accompanied addition in the latter case. Bromine con-verts limonene into limonene tetrabromide. Limonene is converted into limonene nitrosochloride by the action of nitrosyl chloride or of ethyl nitrite and hydrochloric acid at the temperature of a freezing mixture. In like manner α-pinene gives rise to α-pinene nitrosochloride. The nitroso-chlorides of limonene and α-pinene differ in crystal form; upon this fact Chace has recently based a microchemical method for the detection of the presence of oil of turpentine in oil of

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[3] Pharmacopœia of the United States of America, Eighth Decennial Revision, 450.

Limonene

Limonene Tetrabromide

Limonene Monohydrochloride

Dipentene Dihydrochloride

Limonene Nitrosochloride

Limonene Nitrosate
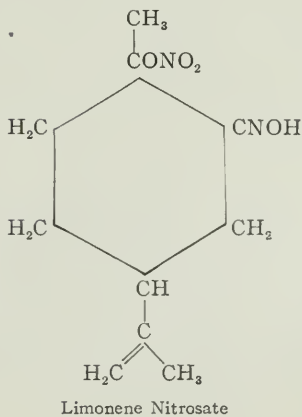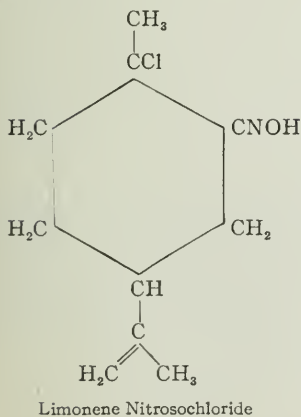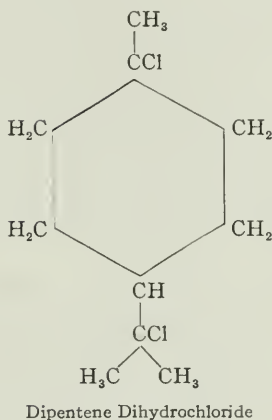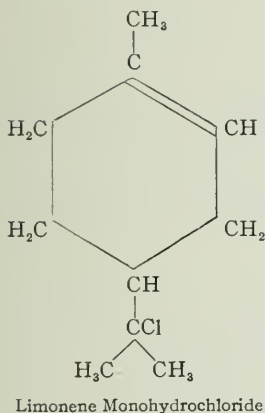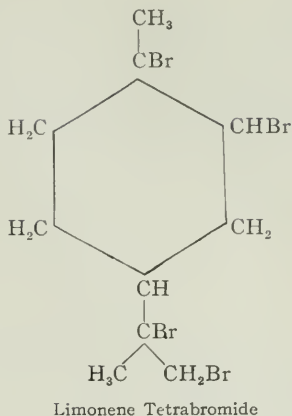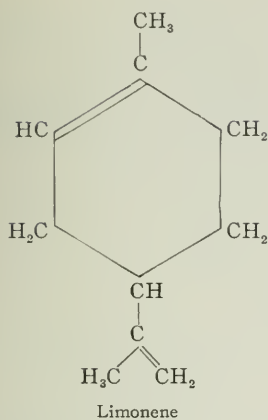
lemon.[4] Limonene reacts with nitrogen peroxide or a mixture of ethyl nitrite and nitric acid to form limonene nitrosate.

Nitrous anhydride may become attached at the double bond with the formation of either a nitrosite or a nitrite; each of these compounds contains a characteristic group:

$$-\overset{|}{C}-O-N=O \qquad -\overset{|}{C}-N\overset{\diagup O}{\diagdown O}$$
$$-\overset{|}{C}-N=O \qquad -\overset{|}{C}-N=O$$
$$\text{Nitrosite} \qquad\qquad \text{Nitrite}$$
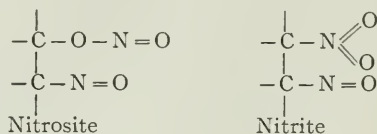
a-Terpinene gives rise to a nitrosite, while a-phellandrene forms a nitrite.

The nitroso group $-N=O$ of the addition compounds frequently is converted into the isonitroso group $=N-OH$.

a-Pinen adds water to form terpin hydrate, which is 1, 8-cis-terpine containing one molecule of water of crystallization. It is prepared [5] by the action of a mixture of one part of nitric acid and three parts of alcohol of specific gravity 0.863 on four parts of rectified oil of turpentine at ordinary temperature. By a similar reaction, terpineneterpin or 1, 4-terpin is obtained by shaking sabinene with dilute sulphuric acid.

Nitrolamines are compounds obtained by the action of ammonia or amines on the nitrosochlorides or nitrosates of the terpenes. Thus limonene nitrosochloride and benzylamine react to form limonene nitrolbenzylamine.

The terms 1, 4-terpin, 1, 8-terpin are based upon a nomenclature in which the carbon atoms of the carbon skeleton of p-cymol are designated by numerals. The carbon atoms of the nucleus are numbered from the top, clockwise, from 1 to 6; the carbon atom of the methyl group is 7; the tertiary carbon atom of the isopropyl group is 8, and the other carbon atoms

[4] Chace, Journal of the American Chemical Society, 1908, xxx, 1475; United States Department of Agriculture, Bureau of Chemistry Circular No. 46, 1909. (The technology of oil of lemon is discussed by Chace in several papers: Yearbook of the United States Department of Agriculture, 1908, 333; United States Department of Agriculture, Bureau of Plant Industry, Bulletin No. 160, 1909, 35; Journal of Industrial and Engineering Chemistry, 1909, i, 18.)

[5] Dispensatory of the United States of America,'Nineteenth Edition, 1249.

α-Terpinene

α-Terpinene Nitrosite

α-Phellandrene

α-Phellandrene Nitrite

α-Pinene

1, 8-Terpin Hydrate
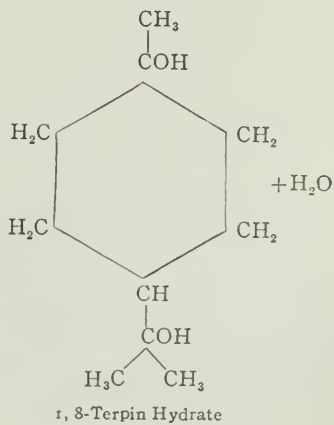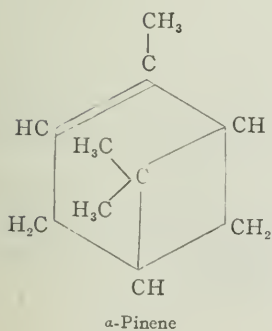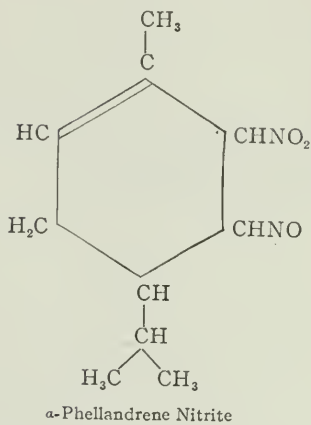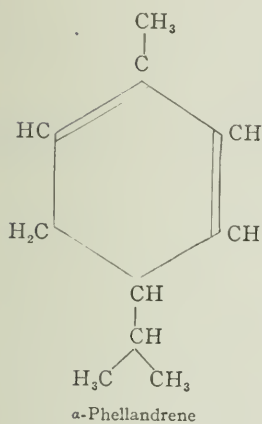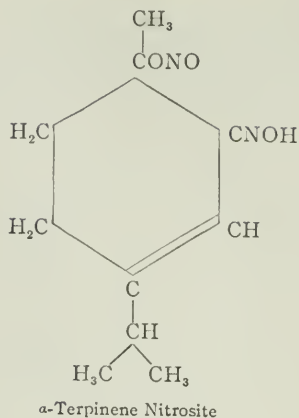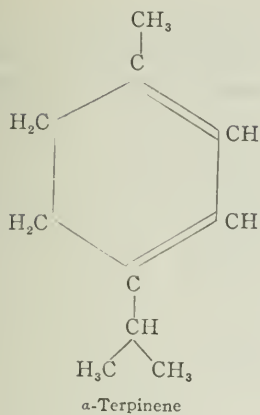
of that group are 9 and 10. Hence, 1, 8-terpin is a glycol with its two hydroxyl groups attached to carbon atoms 1 and 8 respectively. This nomenclature is applied to the terpenes
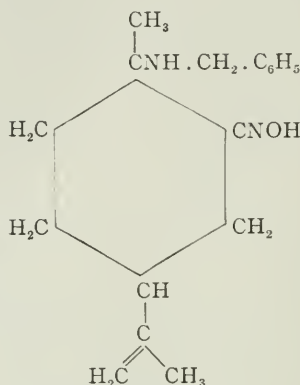
Limonene Nitrolbenzylamine

and their derivatives and, in modified form, to other carbocyclic compounds.
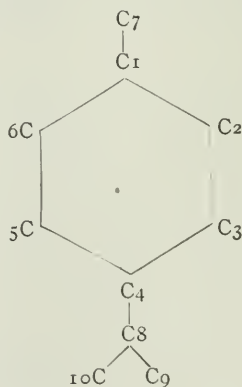
Carvon is an unsaturated cyclic ketone, two molecules of which form an addition product with one molecule of hydrogen sulphide.

Since the cyclic ketone eucarvon contains an ethylene bond adjacent to the carbonyl group, it is able not only to form an oxime, but also to add hydroxylamine at that double bond with the formation of an oxaminooxime.
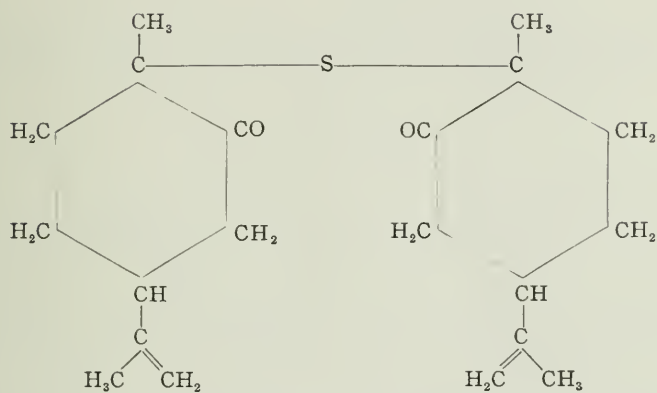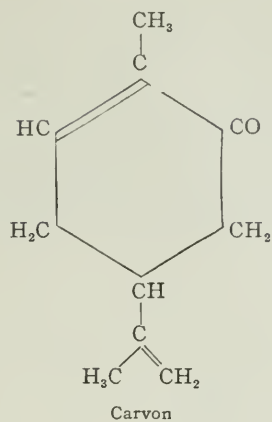
Carvon

Addition Product of Carvon and Hydrogen Sulphide
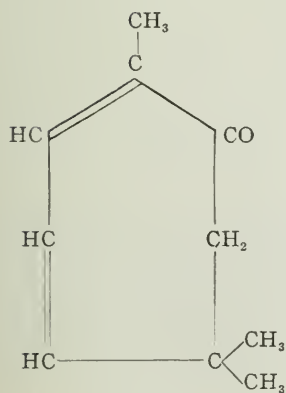
Eucarvon
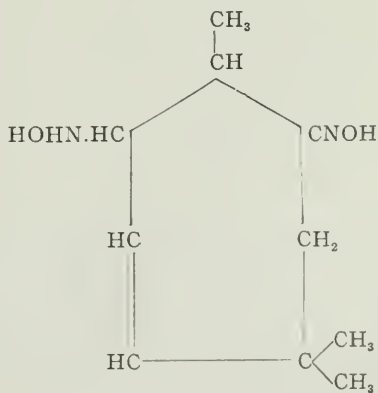
Oxamino-oxime of Eucarvon

HOMOLOGUES OF THE TERPENES.

Both higher and lower homologues of the terpenes have been prepared. Homodipentene is the next higher homologue of dipentene,—*dl*-limonene,—it is synthesized from β-pinene. Upon oxidation β-pinene gives rise to nopinon, a cyclic ketone; this ketone was the first terpene derivative, lacking a side

Nopinon

Ethyl Nopinol
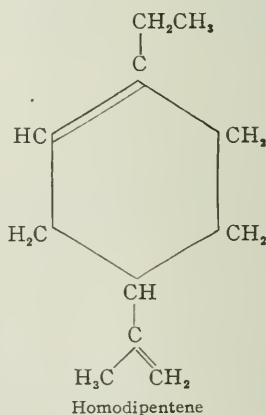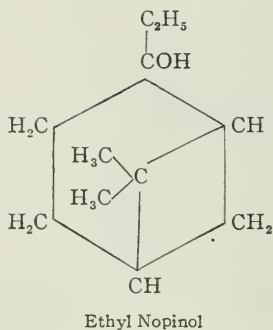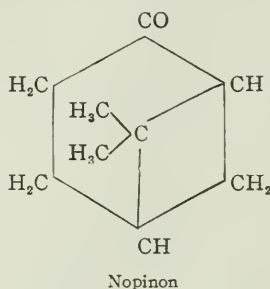
Homodipentene

chain, in which optical activity was observed. By treatment with ethyl magnesium iodide according to Grignard's reaction, nopinon may be converted into an alcohol, ethyl nopinol, which reacts with hydrogen chloride to form homodipentene-dihydrochloride; by splitting off haloid acid from the latter, homodipentene $C_{11}H_{18}$ is obtained.

Dihydro-m-xylol is a lower homologue of the terpenes. It is prepared by heating the unsaturated aliphatic ketone,
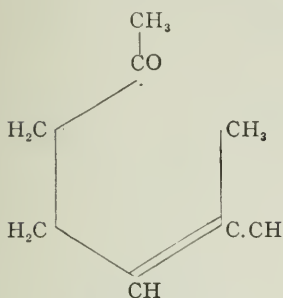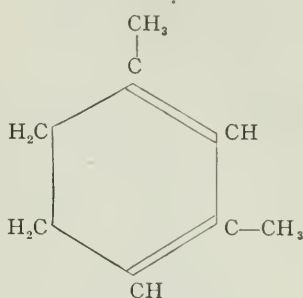
Methylheptenon   Dihydro-m-xylol

methylheptenon, with zinc chloride or dilute sulphuric acid. The ketone splits off water and a carbon ring is formed.

TERPENE ALCOHOLS.

The terpineols are unsaturated monohydric alcohols theoretically derived from 1, 8-terpin by elimination of one molecule of water. Theory calls for four isomers, a-, β-, γ- and δ-terpineol, of which the first three have been prepared; δ-terpineol is still unknown. In like manner terpineneterpin may give rise to a set of four unsaturated monohydric alcohols, one of which is γ-terpineol; the others are known as terpinenol-1, terpinenol-4, and semicyclic terpinenol-4. Methyl nopinol or pinene hydrate is a monohydric alcohol containing an intracyclic bridge; it is prepared by Grignard's reaction from nopinon and methyl magnesium iodide. β-Pinene glycol is a dihydric alcohol obtained by careful oxidation of β-pinene; other glycols are 1, 8-terpin and terpineneterpin which have already been described. Of the glycerols or trihydric alcohols, mention may be made of those obtained from terpinenol-1 and terpinenol-4 by oxidation with permanganate.

Erythrites or tetrahydric alcohols of the terpene series have also been prepared, e.g., terpinolene-erythrite, by the oxidation of terpinolene with permanganate.

The oxide cineol (1, 8-cineol) or eucalyptol, which occurs in the oils of eucalyptus, cajeput, and wormseed, is the oxide

CH₃
|
C

HC   CH₂

H₂C   CH₂

CH
|
COH

H₃C   CH₃

α-Terpineol

CH₃
|
COH

H₂C   CH₂

H₂C   CH₂

CH
|
C

H₃C   CH₂

β-Terpineol

CH₃
|
COH

H₂C   CH₂

H₂C   CH₂

C
‖
C

H₃C   CH₃

γ-Terpineol

CH₂
‖
C

H₂C   CH₂

H₂C   CH₂

CH
|
COH

H₃C   CH₃

δ-Terpineol

CH₃
|
C

H₂C   CH

H₂C   CH₂

COH
|
CH

H₃C   CH₃

Terpinenol-4

CH₃
|
COH

H₂C   CH₂

HC   CH₂

C
|
CH

H₃C   CH₃

Terpinenol-1

CH₂
‖
C

$$\begin{array}{c} CH_2 \\ \| \\ C \end{array}$$
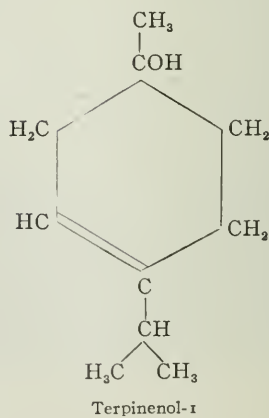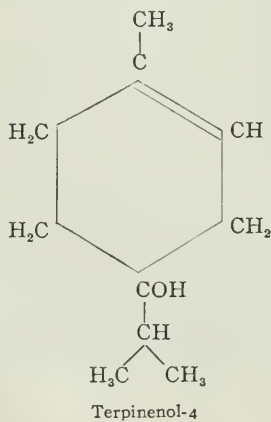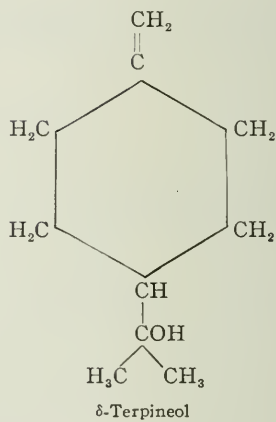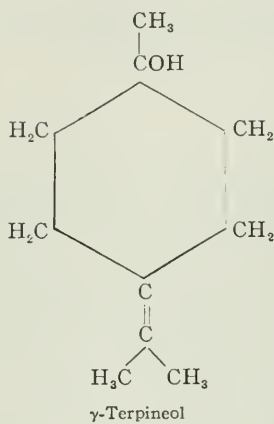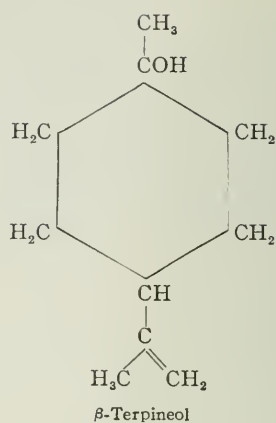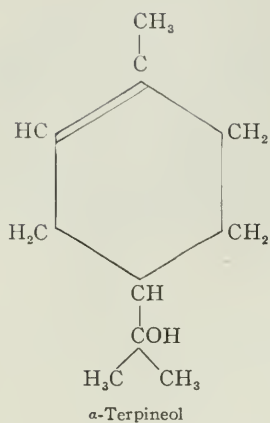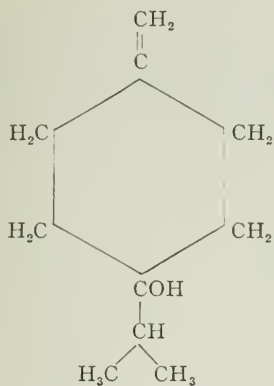
Semicyclic Terpinenol-4
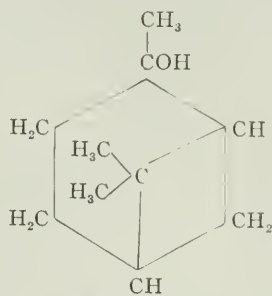
Methyl nopinol
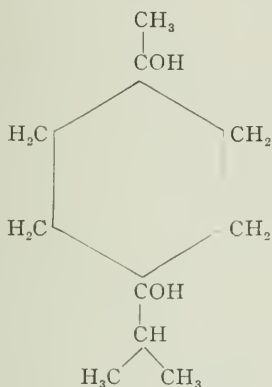
Terpineneterpin—1, 4-Terpin
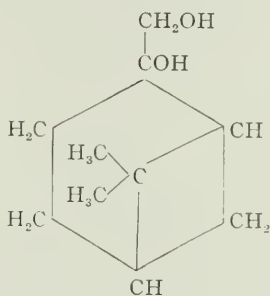
β-Pinene glycol
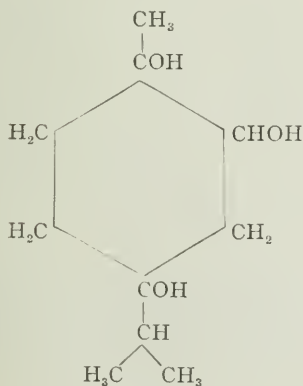
Glycerol from Terpinenol-4
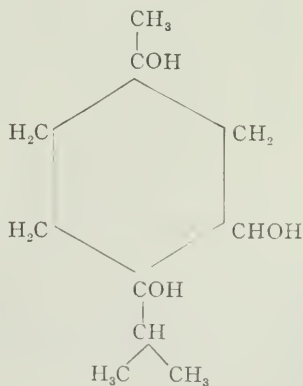
Glycerol from Terpinenol-1

derived from 1, 8-terpin and has been obtained by the action
of acids on terpin hydrate. Of the synthetic oxides, mention
may be made of pinol and 1, 4-cineol; the latter is derived

Terpinolene-erythrite

Pinol

1, 8-Cineol—Eucalyptol

1, 4-Cineol
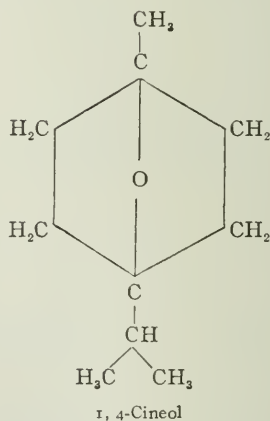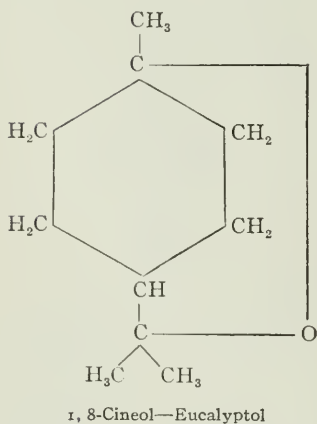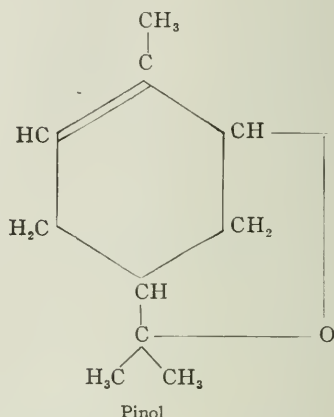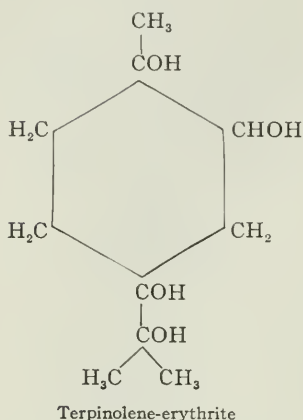
from terpineneterpin. These oxides stand in the same rela-
tion to the corresponding glycols, as ethylene oxide does to
ethylene glycol.

OXONIUM COMPOUNDS OF THE TERPENE SERIES.

Oxonium compounds contain a tetravalent oxygen atom. Halogens and haloid acids become attached to the oxygen atom of certain derivatives of the terpenes and thus give rise to oxonium compounds. Thus the oxide cineol forms oxonium

1, 8-Cineol

With Hydrochloric Acid   With Iodine
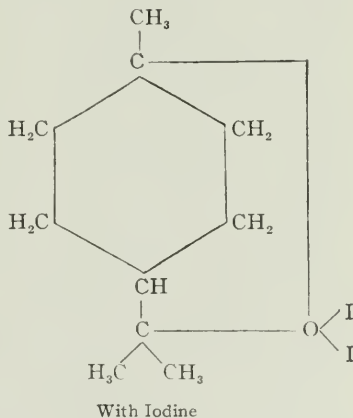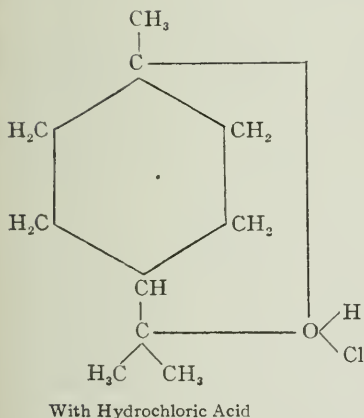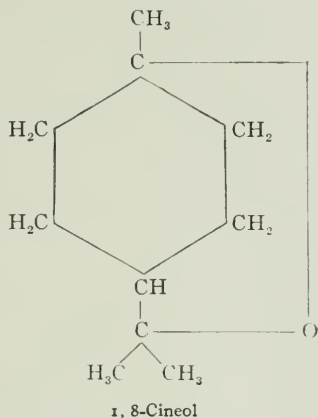
Oxonium Compounds of 1, 8-Cineol

compounds with hydrochloric, hydrobromic and hydriodic acids and with bromine and iodine.

The camphor, fenchone, and bromine react to form an oxonium derivative.

THE CAMPHORS.

The group of camphors includes several alcohols and ketones which are closely related to the terpene hydrocarbons, and have the molecular formula $C_{10}H_{16}O$, $C_{10}H_{18}O$, or $C_{10}H_{20}O$. The generic term camphor is applied to camphor, fenchone, borneol, fenchyl alcohol, menthol, and occasionally to thymol. Borneol is the secondary alcohol derived from the ketone camphor, while fenchyl alcohol is the secondary alcohol derived from the ketone fenchone. Camphor and fenchone have the formula $C_{10}H_{16}O$, borneol and fenchyl alcohol the formula $C_{10}H_{18}O$, all four of these camphors are saturated compounds and contain a carbon bridge in the molecule. Menthol $C_{10}H_{20}O$ is a saturated secondary alcohol, derived from the cyclic ketone menthon. Thymol or thyme camphor is not a true camphor, but is a simple hydroxycymol.

d-Camphor is obtained by distilling the wood of the camphor tree, *Cinnamomum camphora*, with steam; l-camphor occurs in oil of tansy and oil of *Matricaria Parthenium*. The manufacture of inactive camphor is based on the following reaction: when oil of turpentine is heated with oxalic acid, oxalate of borneol $C_{10}H_{17}OOC.COOH$ is formed, this compound upon oxidation passes into inactive (racemic) camphor.[6]

d-Borneol is found in the trunk of *Dryobalonops camphora*, l-borneol in oil of valerian. When the alcoholic solution of camphor is treated with metallic sodium, the nascent hydrogen reduces the camphor to borneol. Borneol is oxidized to camphor by nitric acid and is converted into camphene, a terpene, when heated with potassium bisulphate.

d-Fenchone occurs in oil of fennel, l-fenchone in thuja oil. Sodium and alcohol reduce fenchone to fenchyl alcohol, thus d-fenchone becomes D-l-fenchyl alcohol; the l- signifies that this fenchyl alcohol is lævo rotatory, the D that is derived from d-fenchone. If D-l-fenchyl alcohol be treated with chloride of phosphorus and the mixture be cooled during the reaction, a fenchyl chloride is formed, which loses hydrochloric acid and is converted into D-l-fenchene, a terpene, when heated with aniline.

Menthol is a saturated cyclic secondary alcohol; it occurs as l-menthol in oil of peppermint, which also contains the corresponding cyclic ketone, lævo rotatory menthon.

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[6] Meyer und Jacobson, Lehrbuch der organischen Chemie, 1902, ii, 1031.

Camphor

Borneol

Fenchone

Fenchyl Alcohol

Menthol

Thymol
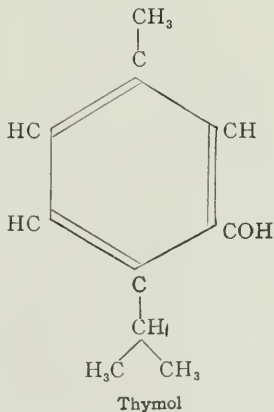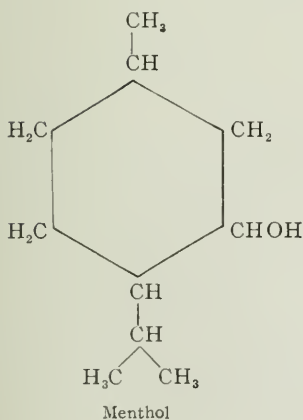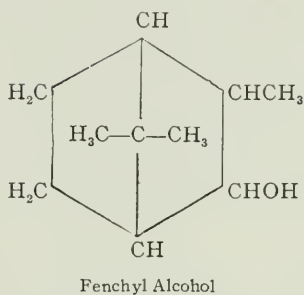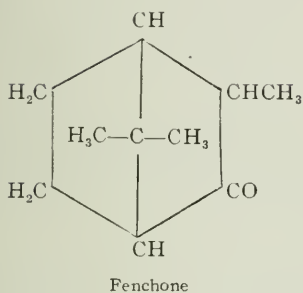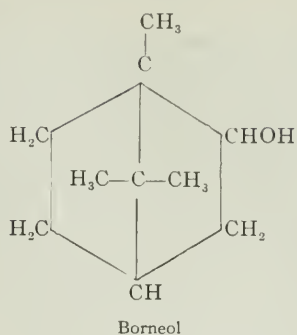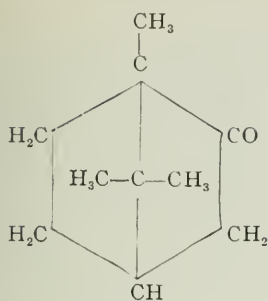
THE SESQUITERPENES.

The sesquiterpenes have the formula $C_{15}H_{24}$. They contain either one or two ethylene bonds, and probably are polycyclic compounds. Cadinene, which occurs in oil of cade and other essential oils, was the first sesquiterpene to be isolated in the pure state. Other sesquiterpenes are caryophyllene, clovene, patchoulene, and guajene. Caryophyllene, clovene and patchoulene have the formula $C_{15}H_{24}=$, cadinene the formula $C_{15}H_{24}\overline{}_2$. The symbol $=$ signifies the presence of one double bond in the molecule; the symbol $\overline{}_2$ the presence of two double bonds.

Caryophyllene, which occurs in oil of cloves, adds water to form caryophyllene-alcohol $C_{15}H_{25}OH$. This alcohol is converted into clovene by the action of dehydrating agents. Caryophyllene-alcohol gives rise to an iodide $C_{15}H_{25}I$, which reacts with metallic sodium to form a saturated hydrocarbon, $C_{30}H_{50}$, dicaryophyllane.

Diterpenes $C_{20}H_{32}$, triterpenes $C_{30}H_{48}$ and tetraterpenes $C_{40}H_{64}$ are also known.[7] Thus elemi resin contains a substance known as amyrin, which has been separated into two isomeric triterpene alcohols $C_{30}H_{49}OH$, known as a- and β-amyrin.

THE CYCLIC KETONES.

The cyclic ketones are hydroaromatic ketones, in which the carbon atom of the carbonyl group forms part of the
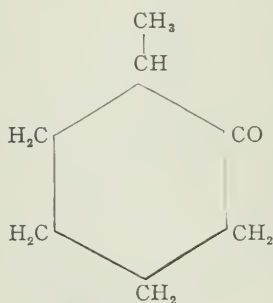
1, 2-Methyl cyclohexanon
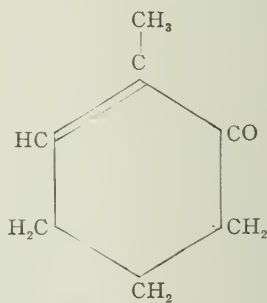
1, 2-Methyl cyclohexenon

ring or nucleus of the molecule. The names of the saturated cyclic ketones end in -anon, of the unsaturated in

[7] Heusler-Pond, The Chemistry of the Terpenes, 431–435.   Blakiston, 1902.

-enon, *e.g.*, 1, 2-methyl cyclohexanon, and 1, 2-methyl cyclohexenon.

In the study of the cyclic ketones, methods have been devised for opening, closing and widening the carbon ring.

The cyclic ketone, cyclopentanon, forms an oxime, which is converted into an isoxime or lactam by the action of sulphuric acid; the carbocyclic ring of five carbon atoms is converted into a heterocyclic ring of six atoms, five of carbon and one of nitrogen. If the isoxime be boiled with concentrated hydrochloric acid, the ring is opened with the formation of δ-aminovaleric acid, an aliphatic compound.

Cyclopentanon

Cyclopentanon Oxime

Cyclopentanon Isoxime

$$NH_2CH_2CH_2CH_2CH_2COOH$$
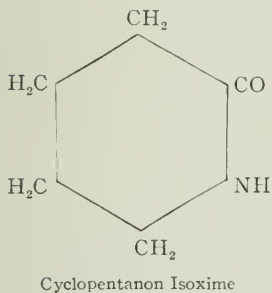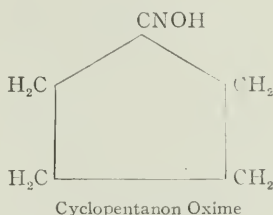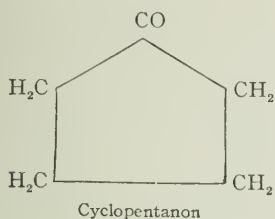
δ-Aminovaleric Acid

The closing of the ring has already been illustrated by the synthesis of dihydro-m-xylol from the unsaturated aliphatic ketone, methyl heptenon.

The widening of the ring may be illustrated by the transition from cyclopentanon to cyclohexanon. Cyclopentanon, bromacetic ester and zinc react in benzol solution to form cyclopentanolacetic ester, which is converted into cyclopentylacetic acid by the action of hydrobromic acid followed by reduction with zinc dust. This acid forms an amide, cyclopentylacetamide, which undergoes Hofmann's reaction

with the formation of an amine, cyclopentylmethylamine. When nitrous acid acts upon this amine, the product is not cyclopentylmethyl alcohol, but cyclohexanol; the carbon

Cyclopentanon

Cyclopentanolacetic Ester

Cyclopentylacetic Acid

Cyclopentylacetamide

Cyclopentyl-methylamine

Cyclohexanol
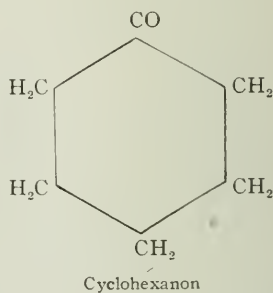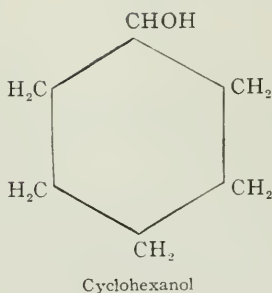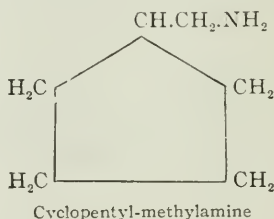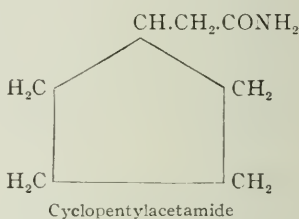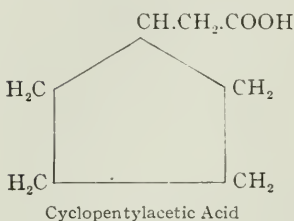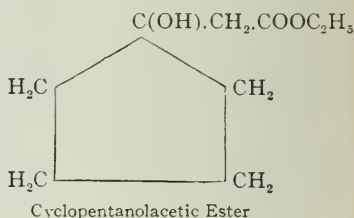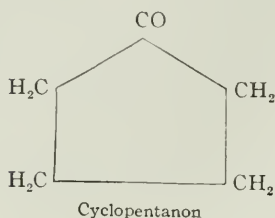
Cyclohexanon

atom of the side chain has entered into the nucleus and a ring of five carbon atoms has been converted into a ring of six carbon atoms. Cyclohexanol may be oxidized to cyclohexa-

non, from which in a similar way may be synthesized cyclo-heptanon and then, from the latter, cyclooctanon.

Certain cyclic ketones occur in the essential oils. Oil of peppermint contains menthon, oil of pennyroyal pulegon, oil of curled mint carvon, thuja oil a-thujon and oil of tansy β-thujon. Menthon is the ketone corresponding to the cyclic secondary alcohol menthol which has been described under the camphors; a- and β-thujon are physical isomerides. The formulæ of pulegon and carvon have already been given; the formulæ of menthon and thujon follow.

Menthon   Thujon
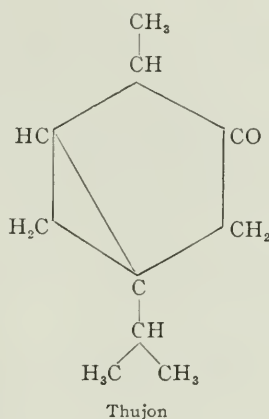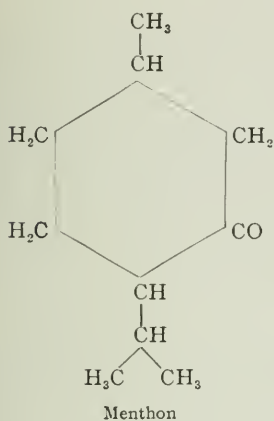
Wallach has performed a difficult and tedious task. He has made straight many crooked paths and has illumined a field of organic chemistry which is of deep interest to every student of both pure and applied chemistry. His work stands as a classic and he has won for himself a place among the masters of chemical science. It is but fitting and proper that, among the honors that have come to Wallach, is the recent award of the blue ribbon of the world of science, the Nobel Prize for work in chemistry.

Artificial Illumination of a Picture Gallery. (*Elect. Rev. and West. Electn.,* lvii, 519.)—A picture gallery at Hartford, Conn. is illuminated by daylight exclusively by overhead skylights. To avoid suspended fixtures and to imitate the conditions of daylight for artificial illumination, sixty-watt tungsten lamps were employed, on account of the resemblance of their spectrum to that of daylight. They were installed two feet above sheets of special sand-blasted glass and equipped with special deflecting mirrors. The intensity of the light was softened by the frosted glass, and the concentrating mirrors were so arranged as to throw the light mainly on the walls instead of allowing it to waste on the floor. The effect is compared to that of the direct rays of the sun shining through a slight mist, which mitigates the glare without absorbing too much light.

Tests of a Moore-Tube Lighting Installation. E. P. HYDE and J. E. WOODWELL. (*Illum. Eng.,* iii, 615.)—This paper describes tests of the energy consumed and the resulting illumination and flux of light developed in such an installation at the New York postoffice. The illumination varies from about 2.5 to 10.5 candle-ft., and the watts per sq. foot of floor area are 2.85. Particulars are given of the stroboscopic test of the oscillations in the light, which are appreciable. It is suggested that a better result can be secured by dividing the tube system into two halves, run off phases 90° apart.

Radio-active Recoil. L. WERTENSTEIN. (*Le Radium,* vii, 288.)—The author has previously shown that the atoms of Ra B projected by recoil of the α particles from Ra A have a range of about 0.12 mm. in air at atmospheric pressure. Active deposit from Ra Em was deposited on glass and a layer of silver deposited above it. A silver layer $10 \mu \mu$ thick allowed most of the recoil particles to pass through it, while a layer $20 \mu \mu$ thick completely stopped them. The range of the recoil Ra B-particle in hydrogen was found to be 0.7 mm. at atmospheric pressure. Experiments on the ionization close to a source of Ra C lead to the conclusion that the recoil Ra D-particles contribute a measurable amount to the initial ionization. Experiments on recoil phenomena in Ra Em, in which Ra A was collected on a positively charged plate, suggested that on the stoppage of Ra A particles in the gas a small percentage of them became negatively charged.

Radium in Great Britain. (*Brit. and Col. Druggist,* 1910, 333.)—According to Sir W. Ramsay the Trenwith mine, in Cornwall, has yielded some 5000 mg. of radium product containing about 10 per cent. of pure radium-bromide. This is the first lot extracted in Great Britain from British ore. Polonium and actinium also exist in the concentrates of the pitch-blende from Cornish mines.

THE RELATION OF CERTAIN NON-LEGUMINOUS PLANTS TO THE NITRATE CONTENT OF SOILS.

BY

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SOME RELATIONS BETWEEN SOIL TEMPERATURE AND NITRIFICATION.

Records were kept of the daily soil temperatures taken at 4.30 P.M. on certain unfertilized plats at a depth of six inches during the growing seasons of 1907 and 1908. In Table VIII

TABLE VIII.

AVERAGES OF DAILY SOIL TEMPERATURES AT DEPTH OF SIX INCHES FOR THE PERIODS INTERVENING BETWEEN NITRATE DETERMINATIONS ON CROPPED SOIL.

TIMOTHY, 1907

Plat No.	June 7–13		June 14–20		June 21–July 24	
	Temp. F.	Nitrates, p.p.m.	Temp. F.	Nitrates, p.p.m.	Temp. F.	Nitrates, p.p.m.
711	60.0	4.6	65.3	3.9	68.1	5.3
720	60.5	1.8	66.5	1.2	69.2	2.9

CORN, 1908

Plat No.	June 2–22		June 23–July 6		July 7–28		July 29–Aug. 10	
	Temp. F.	Nitrates, P.P.M.	Temp. F.	Nitrates, p.p.m.	Temp. F.	Nitrates, n.p.m.	Temp. F.	Nitrates, n.p.m.
711	66.8	40.3	69.2	62.0	69.4	182.0	72.2	162.5
720	65.9	31.5	69.8		69.8	211.0	71.1	136.5

the average temperatures for the periods between the dates on which nitrates were determined are stated, also the nitrate content at the end of the period.

In the year 1907 the nitrates were quite constant in amount throughout the season in spite of changes in soil temperature. This is probably on account of the heavy draft of the timothy crop on the soil nitrates. In 1908 the nitrates increase in quantity up to July 28 although the average temperature from July 6 to that date is practically constant. Between July 28 and Aug. 10 there is a very marked rise in temperature in both plats, but it is accompanied by a decrease in nitrates. The temperatures reached in these plats are not high enough to have any depressing effect on nitrification, as has been demonstrated by many experiments. The results merely indicate as in the case of soil moisture, that the nitrifying process is here determined by other factors. The temperature and moisture content of the soil are evidently not the controlling conditions upon which nitrification on these plats depended.

EXPERIMENTS WITH CORN IN WHICH OTHER PLANTS WERE SOWN.

In 1907 and 1908 certain field plats were planted to corn between the rows of which other plants had been sown broadcast. A part of each plat was not planted to corn, but when the other seed was sown between the corn rows it was also sown on the part of the plat on which no corn was planted. In 1907 the corn was in the centre section of the plat and the sections not planted to corn were on the two ends. In 1908 corn was on the end sections and none in the middle. These plats were not on the same soil in 1908 as in 1907. In 1907 the plats were on a sandy soil while in 1908 they were on the clay loam on which the experiments already discussed were conducted. Diagrams I and II show the arrangements of these plats.

The soil samples were taken with a soil auger to the depth of seven inches. Each sample in 1907 was secured as follows:

Six borings were made, carefully mixed on a tablet in the field, placed in a tightly closed jar and carried to the laboratory for moisture and nitrate determinations. In 1908 four borings were made in each end of the plat, the eight borings from the two ends of the same plat were mixed and a portion taken as a sample. Samples from the middles were composed of six borings.

EXPERIMENTS IN 1907.

Corn was planted in hills three feet apart each way. Five kernels were planted in each hill and these were later thinned to three stalks per hill. Millet was sown on certain plats and soy beans on others. These were sown when the corn was cultivated on the dates stated in Table X. Every third plat

DIAGRAM I.

BARE SPACE   BARE SPACE

15 FT.   45 FT.   15 FT.
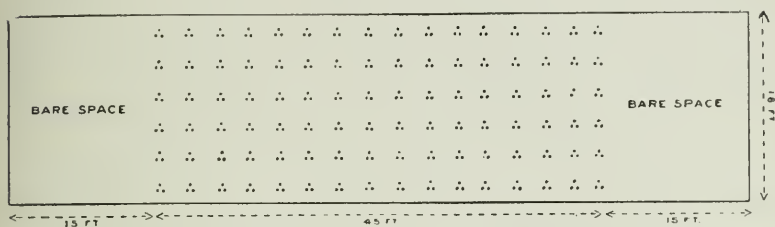
SCALE 2 MM = 1 FOOT

DIAGRAM II.

BARE SPACE

15 FT.   20 FT.   15 FT.
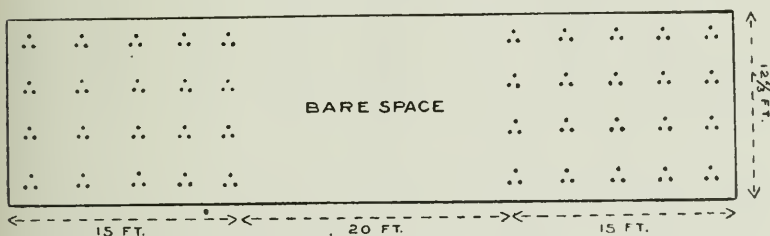
SCALE 2 MM = 1 FOOT

was a check plat and was planted to corn only, in which the weeds were kept down by cultivation. The unplanted ends received the same cultivation as the remainder of the plat. Nitrates on the planted and unplanted sections are given in Table IX.

The analyses were all made late in the growing season when the growth of corn had reduced the nitrates in the planted sections below that in the bare sections. The nitrate content of the unplanted soil is fairly constant until late in the season, when conditions in September being evidently favorable for the process

of nitrification the analysis of the 16th shows that the nitrates
have more than doubled since the analyses of August 25. This
may have been due to the abundant rainfall during the early
part of September, there having been 2.53 inches between Sept. 1
and 16, while there was only 0.73 inches between Aug. 1
and 31. On Sept. 9 there was a rainfall of 1.06 inches, but
although this is a very sandy soil there could have been very
little leaching of nitrates judging from the nitrate content on
the 16th.

Notwithstanding the very favorable conditions for nitrifica-
tion and the large nitrate content of the unplanted soil, there
is practically no increase of nitrates in the planted soil. This
is a striking exemplification of the hypothesis previously ad-

TABLE IX.

NITRATE (NO_3, P.P.M., DRY SOIL) IN CORN AND IN UNPLANTED SECTIONS
OF PLATS 1, 4, 7, 10, 13, IN 1907.

Plat No.	August 5		August 19		August 25		September 16	
	Corn	Bare	Corn	Bare	Corn	Bare	Corn.	Bare
1	51.9	90.0	18.6	72.0	14.8	69.6	12.6	130.0
4	49.2	111.0	16.5	84.0	16.5	91.8	15.0	208.0
7	63.0	96.0	8.8	54.0	10.5	79.8	36.0	143.0
10	23.6	73.1	13.7	50.5	31.0	69.3	30.8	165.0
13	18.1	56.1	29.7	78.6	41.5	69.3	55.0	183.1
Average	41.1	85.2	17.5	67.8	22.8	75.9	29.9	165.8

vanced, namely, that at least certain plants, in some way, inhibit
the formation of nitrates in the soil during the later stages of
their growth. It is certainly impossible to account for the failure
of the nitrates on the cropped soil to increase by supposing that
they were leached out of the top soil, as they would not have
remained practically constant while the nitrates on the uncropped
soil doubled.

The plats sown to millet and soy beans afford an opportunity
to study the effect of these crops on the nitrate content of the
soil by comparing the ends of the plats, which, as already ex-
plained, were sown either to millet or soy beans alone, with the
unplanted ends of contiguous plats. Such a comparison is made
in Table X.

There does not seem to be much tendency for the nitrates

to increase under either of these crops during the early stages of growth; yet those crops which were planted after the first analysis was made, thus permitting frequent observation, display something of this tendency. Thus comparing the nitrates under millet sown July 24 on Plat 6 with those in the check Plats 4 and 7 it will be seen that the first determination of nitrates after the millet was up showed an increase in all three plats, but the increase under the millet was 61.6 p.p.m., while that under the checks was 19.2 and 28.2 p.p.m. respectively. The millet sown on Aug. 6 did not make much growth. The decrease in

<div align="center">TABLE X.</div>

Nitrates (NO$_3$, p.p.m., Dry Soil) in Millet or Soy Beans Alone and in Unplanted Sections of Adjacent Plats in 1907.

Date	Plat 5 Millet,[1] sown June 18	Plat 4 Bare	Plat 6 Millet,[2] sown July 24	Plat 7 Bare	Plat 8 Millet,[3] sown Aug. 6	Plat 10 Bare	Plat 9 Soy beans,[4] sown July 5	Plat 11 Soy beans,[5] sown July 24	Plat 13 Bare
July 9	84.8	98.0	79.0	99.1	100.0	54.4	98.6	53.0	57.5
July 15	72.8	88.4	78.0	81.9	61.7	33.6	60.3	26.4	30.0
July 22	29.9	110.0	113.7	78.4	101.4	84.0	75.6	73.8	81.6
July 29	6.6	91.8	73.4	67.8	79.8	52.2	19.2	54.0	60.0
Aug. 5	2.2	111.0	135.0	96.0	135.0	73.1	8.8	56.6	56.1
Aug. 12	6.5	96.0	81.6	84.0	111.0	62.1	4.0	75.0	78.6
Aug. 19	1.5	84.0	60.0	54.0	84.0	50.5	3.0	55.0	78.6
Aug. 25	2.0	91.8	41.2	79.8	93.6	69.3	2.0	55.0	69.3
Sept. 2	1.0	96.0	25.3	73.8	66.0	87.6	2.0	52.2	90.0
Sept. 16	2.2	208.0	6.0	143.0	45.0	165.0	10.0	145.0	183.1

[1] Yield per acre, 4999 lbs. dry matter.
[2] Yield per acre, 2026 lbs. dry matter.
[3] Yield per acre, 772 lbs. dry matter.

[4] Yield per acre, 3700 lbs. dry matter.
[5] Yield per acre, 894 lbs. dry matter.

nitrates between Analyses of Aug. 12 and 19 under the millet on Plat 8 was 27.0 p.p.m. as against 30.0 and 116.6 p.p.m. on Plats 7 and 10 respectively. Plat 9, on which soy beans were sown July 5, shows about the same nitrate content at each analysis up to July 22 as its checks, Plat 7, and Platt 11. Plat 11, which was sown to soy beans on July 24, continues about the same as its checks until Aug. 12. Neither crop can be said to have been associated with any marked increase in nitrates at any stage of its growth, although the nitrate content of the soil under them does not show, in early growth, the decrease that would be expected. There is the same tendency for nitrates to con-

tinue at a low figure throughout the latter part of the season
under millet, as has already been noted under corn. Although
Plat 4 shows an increase in nitrates of from 96.0 p.p.m. on
Sept. 2 to 208.0 p.p.m. on Sept. 16, Plat 5 shows practically
no gain, notwithstanding the fact that the absorption of nitrogen
by the millet crop had practically ceased at that time. The millet
sowings of July 24 and Aug. 6 show this same phenomena.

Soy beans do not exhibit this property to the same degree.

TABLE XI.

NITRATES (NO$_3$, P.P.M., DRY SOIL) IN CORN AND IN UNPLANTED SEC-
TIONS OF PLATS 1, 4, 7, 10, 19, 22, 25 IN 1908.

Plat No.	July 22		Aug. 31	
	Corn	Bare	Corn	Bare
1	85.0	65.8	99.0	79.3
4	66.5	60.4	89.9	82.3
7	78.0	64.0	107.1	78.7
10	74.7	69.1	105.4	48.0
19	171.6	102.4	111.6	82.3
22	140.5	143.0	99.2	75.0
25	140.5	100.7	126.0	75.0
Average	108.1	86.5	105.4	74.4

Between the dates mentioned there was a slight increase in
nitrates under the sowing of July 5, and a marked increase
under the sowing of July 24.

EXPERIMENTS IN 1908.

The plan of experiments in 1908 was primarily the same as
that of 1907, but soy beans were not used and there was a
difference in the arrangement of the planted and unplanted sec-
tions of the plats and the character of the soil, all of which have
before been noted. Analyses were made only on July 22 and
Aug. 31. Table XI contains a comparison of the planted and
unplanted sections of the check plats, all of which received the
same treatment.

The higher nitrate content of the planted soil on July 22 is in line with previous results, but a similar relation on Aug. 31 is not, as the nitrate content under corn is usually low at that time. The growth of corn was very poor on these plats, the plants growing only three or four feet high, and producing only about one-third of a crop of fodder. There was, consequently, a very small absorption of nitrogen as compared with a normal crop. It seems likely that the failure of the crop to utilize the available nitrogen resulted in the high nitrate content as late as Aug. 31.

Millet was sown in the corn and in the middles of certain plats as in 1907, but was not sown on different dates. A mis-

TABLE XII.

Nitrates (NO_3, p.p.m., Dry Soil) in Sections of Plats in Corn and Millet Together, and in Corn and Weeds Together and in Sections of Same Plats in Millet Alone and in Weeds Alone, 1908.

Plat No.	July 22		August 31		
	Corn and millet	Millet	Corn and millet	Millet	
6	76.8	44.1	9.9	4.0	No fertilizer
9	128.0	130.4	13.8	76.5	Nitrate of soda
21	138.8	96.3	45.0	6.0	No fertilizer
24	315.5	258.0	190.0	160.0	Nitrate of soda
	Corn and weeds	Weeds	Corn and weeds	Weeds	
5	84.5	56.3	15.4	7.7	No fertilizer
20	145.2	132.4	12.0	14.0	Nitrate of soda

cellaneous assortment of weed seeds was sown on the ends and middles of other plats. Certain of the plats so treated had an application of nitrate of soda before the corn was planted. Table XII shows the nitrate content of the soil under the corn and millet mixed, the corn and weeds mixed and under millet and weeds alone.

The yields of corn were extremely poor on these plats, being naturally poorer than the check plats that received cultivation.

This is an interesting condition as it gives in some cases about
the same yield of corn and millet combined, as of millet alone,
and the same for weeds.   This is brought out in Table XIII.

On July 22 the nitrates are, in general, higher in the soil
planted to the mixture than in the soil planted to a single crop,
in spite of the fact that the draft on the available nitrogen
must have been nearly the same on both sections.   If it is true
that the early stages of the plant growth favor nitrification in
the soil, and that, as indicated by results already presented, corn
is much more effective in this respect than is millet, the higher

TABLE XIII.

YIELDS ON SECTIONS OF PLATS PLANTED TO CORN AND MILLET AND CORN
AND WEEDS, AND ON SECTIONS PLANTED TO MILLET AND WEEDS ALONE.

Plat No.	Crop on section	Yield of corn, lbs.	Yield of other crop, lbs.	Total yield on section, lbs.	Yields on sections calculated to same area, lbs.
6	Corn and Millet .	3.87	49.63	53.50	35.66
	Millet	. . . .	42.40	42.40	42.40
9	Corn and millet .	6.55	42.39	48.94	32.62
	Millet	. . . .	39.43	39.43	39.43
21	Corn and millet .	3.45	43.60	47.05	31.36
	Millet	. . . .	34.04	34.04	34.04
24	Corn and Millet .	7.91	47.13	55.04	36.68
	Millet	. . . .	36.73	36.73	36.73
5	Corn and weeds .	5.85	22.83	28.68	19.12
	Weeds	. . . .	18.54	18.54	18.54
20	Corn and weeds	5.27	23.73	29.00	19.32
	Weeds	. . . .	20.35	20.35	20.35

nitrate content under the mixture of corn and millet than under
the millet alone is thus readily accounted for.

This experiment, moreover, eliminates the factor of cultiva-
tion, to which the higher nitrate content under corn has usually
been ascribed.   With the corn plats receiving no more cultiva-
tion than the millet plats, and producing practically the same
total quantity of dry matter the higher nitrate content of the
corn soil must be due to some factor other than cultivation.
This again suggests the possibility of a beneficial influence on
nitrification, or the utilization of nitrogen in some form other
than that of nitrates by the corn plant.

THE EXCESSIVE SUPPLY OF NITRATES IN CORN LAND.

Another significant fact brought out by a study of the nitrates under corn is the great excess of nitrates over the apparent needs of the plant during the first half of the growing season. Under oats and millet there appears to be an increase of nitrates during the very early stages of growth, but this quickly disappears as the growth of the plant proceeds. Under grass there is very little or no accumulation of nitrates at any stage during the growth of the first crop of the year. Under corn, however, the nitrates accumulate in apparently excessive quantity up to the middle of the growing season, and this, while the crop is growing actively, and absorbing large quantities of nitrogen.

In order to obtain some idea of the nitrogen absorption during that portion of the growth of the corn plant when nitrates were accumulating as compared with its later growth the figures obtained by Roberts and Wing[7] in 1888 and 1889 with the same variety of corn (Pride of the North), and in the same field as that in which the corn and millet experiments were conducted in 1907, are of interest. In their experiment of 1888 the corn was planted on May 7, and was out of danger of injury from frosts on Sept. 10. Portions of the crop were cut on different dates, weighed and analyzed. From the weights and protein-nitrogen content of the crop on certain dates, the amounts of nitrogen removed from the plants on these dates may be calculated and on the basis of weight and analysis at final harvest, the proportion of the total nitrogen acquired by the plant may be calculated for any of the dates on which the cuttings were made. Estimated in this way the corn plants had absorbed 43 per cent. of their nitrogen on July 24 and 63 per cent. on Aug. 8. In 1889 the corn was planted on May 12, and was mature Sept. 24. On Aug. 2 it had acquired 53 per cent. of its total nitrogen, on Aug. 17, 50 per cent., and on Aug. 31, 67 per cent. The figures for 1889 are somewhat contradictory as the proportion of nitrogen taken up on Aug. 17 was less than on Aug. 2. The figures indicate that at least 50 per cent. of the nitrogen utilized by " Pride of the North " corn in this

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[7] Cornell Experiment Station, Bulletins 4 and 16.

locality in an average year is absorbed by the end of July. Referring to Table III, it will be seen that on July 27, the nitrate content of the soil under the corn on the unfertilized plats was 191 p.p.m., while that on the cultivated soil on which no plants grew was 177 p.p.m. Even as late as Aug. 10, the nitrates under the corn on these plats were 173 p.p.m. and unplanted soil was 185 p.p.m. It is to be expected that there would be a large

DIAGRAM III.
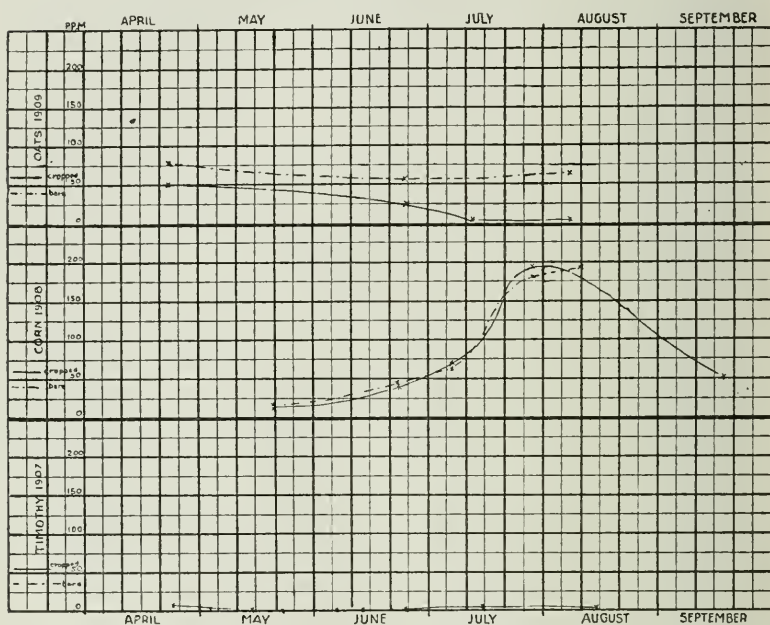
Average nitrate content of soil from eight unfertilized plats during three successive years. A different crop was grown each year and during two years the nitrates are shown on the unplanted sections of the plats. The curves indicate seasonal changes. Nitrates in cropped soil ———. Nitrates in bare soil - - - - - - -

accumulation of nitrates in the cultivated and uncropped soil, but why this should be true of the soil carrying a heavy crop of corn, practically one-half of the nitrogen of which had been absorbed, it is difficult to understand. The formation of nitrates during this period must have proceeded with tremendous activity if nitrates were the only source of nitrogen supply for the crop.

Some conditions indicate that corn, at least during part of its period of growth, utilizes nitrogen quite largely in forms

other than nitrates. Ammonification apparently never proceeds more rapidly than nitrification in normal soils, which would bar that form of nitrogen as a very considerable source of supply. Organic nitrogen in some of its soluble forms is the only remaining alternative. The great benefit derived by corn from the application of farm manure, suggests the possible use of nitrogen in this form.

During the later growth of the corn plant there is a great falling off in the nitrate content of the soil under the plants as compared with the unplanted soil. There seems to be no question that nitrates are absorbed by corn in large quantities during the period of growth during which it is securing the second half of its nitrogen supply. (See Diagram III.)

EXPERIMENTS IN 1910.

During the growing season of 1910, determinations of nitrates were made under corn, potatoes and oats. These were from plats planted to each crop, of which two plats were limed and two unlimed. An unplanted strip ran through the centre of each plat. Soil samples were taken on the planted and unplanted sections of each plat. The sections are designated as " north ends," " middles " and " south ends." The " north ends " and " south ends " were both planted; the " middles " grew no crop, but were given the same soil treatment as the remainder of the plat. This consisted in cultivation on the corn and potato plats, and scraping the surface on the oat plats. Soil samples were taken to a depth of four feet on the " north ends " and " middles," but on the " south ends " were taken to a depth of only one foot, except on May 12, when composite samples from the " north ends " and " south ends " were analyzed.

The soil on which these plats were located was a heavy clay loam in the same field as that in which most of these experiments have been conducted. This particular piece of land was not uniform as regards either production of crops or nitrates. Fortunately each crop was grown on four separate plats and, in spite of irregularities in single plats, the average of the four plats in each crop gives quite concordant results.

The weather during the growing season of 1910 was drier than normal, and the early part of the season was unusually cool.

The yields of oats and potatoes were about average size, but the corn crop was extremely poor. The small corn crop was due to the soil rather than to the weather, as no manure had been applied to the land, and this soil does not produce good yields of corn unless it is well manured. It will be noticed from Table XIV that the nitrates under corn run over a hundred parts per million in the surface foot of soil, in spite of which large quantity of soluble nitrogen the crop was extremely poor. Potatoes and oats made a much better growth and reduced the nitrates considerably lower. This is another example of the slight response of corn to nitrates on this soil.

Planting was performed on the following dates: oats (White Russian) on April 28; potatoes (Enterprise) on May 16; corn

TABLE XIV.

AVERAGE NITRATE CONTENT (NO$_3$ P.P.M.) IN THE SURFACE FOOT OF SOIL OF THE FOUR PLATES PLANTED TO EACH CROP ON THE DATES WHEN ANALYZED.

Crop.	May 12.		June 1.		July 28.		Aug. 17.		Sept. 9.		Oct. 17.	
	Planted.	Not planted.	Planted.	Not planted.	Planted.	Not planted.	Planted.	Not planted.	Planted.	Not planted.	Planted.	Not planted.
Corn............	65.8	56.8	98.5	62.3	167.6	92.1	178.8	166.9	247.5	273.3	244.3	166.9
Potatoes.........	95.1	34.2	121.8	57.8	126.6	145.3	138.6	134.9	99.3	129.7	43.0	145.2
Oats.............	97.1	48.9	125.1	87.8	74.9	84.5	82.1	154.4	66.9	169.7	96.8	210.6

(Pride of the North) on May 21. The oats were harvested on Aug. 7 and the corn and potatoes Oct. 20.

Table XIV contains a statement of the average nitrate content of the surface foot of soil on the cropped and uncropped sections of the four plats planted to each crop. For the cropped sections, the averages include both of the cropped ends of the plats.

An examination of Table XIV shows, so far as the corn crop is concerned, the characteristically higher nitrate content in the planted than in the unplanted soil during the latter part of July. The nitrate content of the planted soil was slightly higher than that of the planted before the crop was seeded, and nitrates continued to develop more rapidly under the corn up to the latter

part of July. From that time until the corn was mature in September, the nitrates under the crop decreased as compared with the unplanted soil in the usual manner, but the analysis of Oct. 17 shows a greater relative increase in the planted soil, which is contrary to the hypothesis which has been advanced. It is possible that the very feeble growth of the crop may account for this, as it evidently was the reason for the slight reduction of the nitrates under the crop through the growing season.

Potatoes, which were a normal crop, gave results similar to those obtained from normal yields of corn. The difference in the nitrate content of the potato plats and of the contiguous corn

TABLE XV.

Nitrates in Each of Upper Four Feet of Soil.

Crop	Depth.	May 12.		July 28.		Aug. 17.		Sept. 9.		Oct. 17.	
		Ends.	Mid.	N. E.	Mid.	N. E.	Mid.	N. E.	Mid.	N. E.	Mid.
Corn........	1	65.8	56.8	173.9	92.1	200.8	166.9	236.5	273.3	309.0	166.9
Corn........	2	33.8	25.1	55.4	47.2	48.8	43.4	78.9	99.6	64.3	57.2
Corn........	3	24.9	16.6	41.2	25.6	44.0	34.3	46.9	56.2	43.2	32.7
Corn........	4	21.2	15.0	43.8	30.6	41.8	24.4	44.7	72.1	50.3	40.4
Total		145.7	113.5	314.3	195.5	335.4	269.0	407.0	501.2	466.8	297.2
Potatoes.....	1	95.1	34.2	154.8	145.3	163.8	134.9	110.3	129.7	35.0	145.2
Potatoes.....	2	39.4	18.8	49.9	44.1	62.8	49.2	52.4	59.9	29.3	42.5
Potatoes.....	3	29.7	19.6	37.3	35.1	44.5	37.8	28.5	38.2	24.7	38.2
Potatoes.....	4	30.7	18.3	34.7	31.2	41.8	36.0	28.5	29.3	26.9	36.6
Total		194.9	90.9	276.7	255.7	312.9	257.9	219.7	257.1	115.9	262.5
Oats........	1	97.1	48.9	196.5	84.5	95.6	154.4	84.0	169.7	152.6	210.6
Oats........	2	32.3	27.5	37.2	33.4	38.7	47.7	28.0	46.6	51.0	53.4
Oats........	3	15.6	11.7	21.3	23.5	28.0	35.4	19.8	45.7	26.7	27.8
Oats........	4	30.8	21.6	21.7	23.2	25.0	30.4	21.7	39.8	27.8	32.7
Total...	......	175.8	109.7	186.7	164.6	187.3	267.9	153.5	301.8	258.1	324.5

plats on Oct. 17 is very marked. Although the vines were dead on this date, the nitrates were lower under the plants than at any period during their growth, while nitrification had again gone forward in the unplanted soil.

Nitrates under the planted and unplanted sections of the oat plats were of the same relation as in previous years. Nitrates continued to decrease after harvest as shown by the analysis of Sept. 9, one month after harvest. A slight increase is shown by the analysis of Oct. 17, but it will be noted that while nitrates in the planted soil increased 14.7 p.p.m. during that time, the unplanted soil shows an increase of 56.2 p.p.m. in its nitrate content.

NITRATES AT DIFFERENT DEPTHS.

In order to ascertain what effect the upward and downward movement of nitrates may have on the apparent connection between the plant and the nitrate content of the surface soil samples were taken on the "north ends" and "middles" of each plat to a depth of four feet, each foot being analyzed separately. The results of these analyses are shown in Table XV.

The analyses show that nitrates are found to a depth of four

DIAGRAM IV.
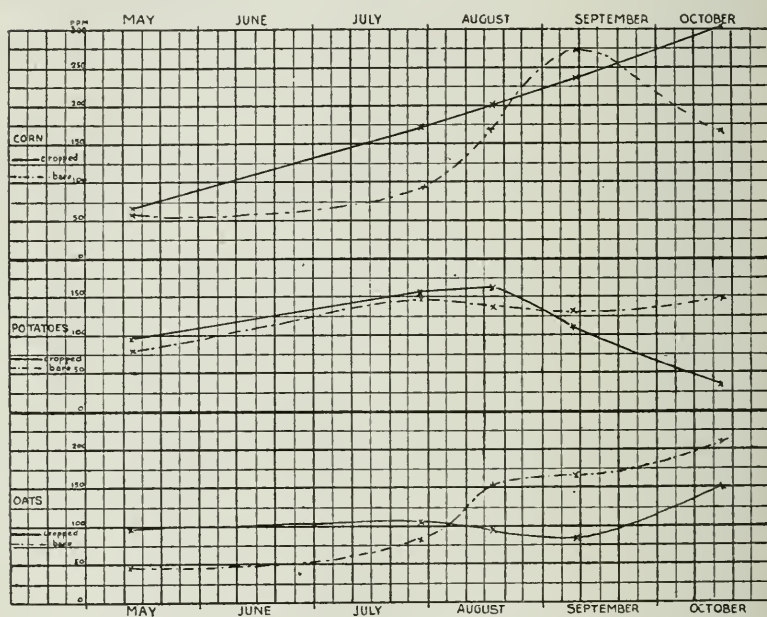
Average nitrate content of soil from planted and unplanted sections of four plats of corn, potatoes and oats in 1910. Nitrates in cropped soil ———. Nitrates in bare soil - - - - - - - -

feet, but that the changes in nitrate content of the soil are not great beneath the first foot. Where changes occur in the second foot, they usually accompany corresponding changes in the surface foot. An increase in the nitrates in the surface foot is seldom accompanied by a decrease in the second foot, as would be the case if the augmented nitrate content of the upper foot were due to an upward movement of the nitrates. On the other

hand, the two upper feet increase or decrease in nitrates on the same dates, indicating a downward movement of the nitrates. It would appear from these figures that the nitrate content of the surface foot is determined, in the main, by the rate of nitrification and by the removal of the nitrates, by various means, from that layer of soil. (See Diagram IV.)

The results of the experiments in 1910 are generally in line with the hypotheses we have advanced to account for the characteristic relations of certain non-leguminous plants to the nitrate content of the soil on which they grow. While these characteristic relations, at least in so far as the soils experimented with are concerned, may be considered to be definitely shown for normal crops by these experiments extending over four years, the hypotheses to account for them are still matters for experimentation, which must be based on somewhat different methods from those used heretofore. That the plant exerts an influence in accelerating or retarding nitrification at certain stages of its growth or afterwards, is indicated by these experiments and will constitute a subject for further investigation.

SUMMARY.

The nitrate content of soil under timothy, corn, potatoes, oats, millet, and soy beans was different for each crop when on the same soil. There was a characteristic relationship between the crop and the nitrate content of the soil at different stages of growth. During the most active growing period of the corn crop, nitrates were higher under corn than in cultivated soil bearing no crop. Under a mixture of corn and millet, nitrates at this period were higher than under millet alone, although the crop yields were about the same on both plats.

These phenomena may be accounted for on the assumption that nitrification is stimulated by some processes connected with the active growth and absorbing functions of plants, particularly of corn, although there are indications that the corn plant obtains a part of its nitrogen in some form other than nitrates, the combination of which conditions may account for the very high nitrate content of the soil under corn.

Under both corn and oats, the nitrate content was higher during the period when the crop was making its greatest draft on the

soil nitrogen than in the later stages of growth, in spite of the fact that the nitrates in the uncropped soil were increasing while those in the cropped soil were disappearing. Nitrates under these crops and under millet failed to increase late in the season, when nitrogen absorption had practically ceased, although uncropped soil showed a very large increase in nitrates at that time.

This in conjunction with facts before mentioned, indicates a further influence of the crop on the process of nitrification, and may be accounted for on the supposition that the plants, during their later period of growth, exert, in some manner, a retarding influence on nitrification.

The large differences in the nitrates under the crops mentioned may, aside from the influence of cultivation, possibly be found in the inherent differences between plants of different species in their stimulating or inhibiting influence on nitrification, as well as in their relative rates and amounts of nitrogen absorption.

Changes in the moisture content, or in the temperature of soil under crops during the growing season, had no important effect on the nitrate content of the soil, except under the legume, soy beans. On uncropped soil an increase in moisture content in September was accompanied by a marked increase in nitrates.

Preparation of Argon. G. CLAUDE. (*Comptes rendus,* cli, 752.) —Oxygen obtained in the liquefaction of air is a suitable material for the rapid preparation of argon. This liquid practically contains over 95 per cent. of oxygen, and its chief impurity is argon, the volatility of which is intermediate to that of oxygen and nitrogen. Thus 96 per cent. oxygen contains normally more than 3 per cent. of argon. To separate this the oxygen may be absorbed by copper and the nitrogen by magnesium. The gas is passed through a copper tube heated to a dull redness. The tube is charged with 2.5 kilos of reduced copper mixed with a little copper turnings to increase its absorptive capacity. From this tube the gas passes through an iron tube containing magnesium powder and red hot, and finally through a heated silicon tube containing copper oxide to absorb any hydrogen derived from the moisture in the copper or the oxygen. By this means 3 litres of gaseous oxygen may be treated per minute and from 4 to 6 litres of argon be obtained per hour. About 8 to 12 litres of argon are obtained before the copper becomes spent. This can be regenerated by hydrogen in about one and a half hours.

FRANKLIN INSTITUTE

REPORT OF THE BOARD OF MANAGERS FOR THE YEAR ENDING SEPTEMBER 30, 1910, WITH APPENDICES EMBRACING THE ANNUAL REPORTS OF THE VARIOUS COMMITTEES AND SECTIONS.

To The Members of the Franklin Institute:

For my re-election to the honorable position of President of Franklin Institute, I thank the membership of the Institute present and absent.

As I have told you before, no part of the very varied work in which I am engaged, gives me more pleasure or has a greater hold upon my interest, than the work of the Franklin Institute.

The past year has seen a material advance in the affairs of the Institute and a material improvement in methods and results. This is due, in part, to an awakened interest in the Institute, and in very large part, to the ability and activity of the secretary, Dr. R. B. Owens, who has joined the force since our last annual meeting.

The work of the standing committees has been improved, and notably that of the Committee on Science and the Arts has been greatly simplified; all as set out in the reports of the committees submitted herewith. These reports bring the record down to September 30, 1910:

We enter now a new year with a permanent secretary,—this for the first time since the resignation of the lamented Dr. Wahl, who was for many years the efficient and self-sacrificing secretary of the Institute. The prospect of future good work was never brighter in the history of the Institute.

The Library is becoming of more and more use to the public; the Schools are more and more attracting the attention of the industrial population of Philadelphia and the classes are gaining in numbers. The work of the Committee on Science and the Arts has proven more and more attractive to men of reputation and ability.

Our finances are still in an unsatisfactory condition, but unsatisfactory as it is, it is an improving condition. The Franklin Fund slowly grows and your Board of Managers have great hope that in a relatively short time we can fix a date for the beginning of the new building, which everyone has very much at heart. We have been disappointed from year to year at not being able to say more definitely that the new building was assured; we have not been disheartened, and while our new building fund has been slowly growing, we have increased our efforts to improve and extend the work that has been carried on in this historic building. When or whether a more commodious and suitable home for Franklin Institute is obtained,

the work will not be permitted to lag, and the effort to prove worthy of our honored predecessors, and to set a noteworthy example for the emulation of our successors, will never be relaxed.

For the Board of Managers,

WALTON CLARK,

President.

PHILADELPHIA, January 18, 1911.

REPORT OF THE COMMITTEE ON INSTRUCTION.

To the Board of Managers:

The Committee on Instruction has pleasure in submitting the following report of its work during the year ending September 30, 1910.

After numerous Committee meetings held during the spring and summer months, the entire curriculum of the school was reorganized and the title formerly known as the " Night Schools," was changed to the " Franklin Institute School of Mechanic Arts." Mr. William H. Thorne was appointed Director, and the following officers of instruction were appointed to assist him in the various departments:

H. P. Tyson, Professor of Mathematics; M. H. Keill, Professor of Naval Architecture; Clement Remington, I. P. Pedrick, A. V. McConnell, Frank H. Lobb, W. N. Twining, Instructors in Drawing; John Burt, Instructor in Mechanics; G. T. Sharp, Instructor in Mathematics.

A new, enlarged and comprehensive pamphlet was issued, descriptive of the various reorganized departments of the School and of the several courses in each department.

The following table shows the registration of students in the various departments:

	Winter Term, 1909.	Spring Term, 1910.
Drawing School	98	67
Mathematics	41	18
Theoretical Mechanics	17	..
Strength of Materials	..	13
Machine Design	5	5
Naval Architecture	12	8
	173	111

As compared with the registration for the year 1909, an increase is shown of 2 students in the Spring Term and 33 students in the Winter Term. The first night's registration in 1911, which was the opening night of the Spring Term of the schools, shows 87 students in one department, as against 45 students in the same department on the opening night in January, 1909; so that the prospects are very bright for a large registration for the year 1911.

Owing to the liberality of the Board of Managers, the School rooms have been thoroughly repainted and renovated, and the light and ventilation greatly improved. These changes have been much appreciated by all who have had occasion to use the rooms, and the regular increased attendance of the students and the improved quality of their work, stand as proof of some of the benefits that have accrued from these improvements.

There were popular lectures delivered during the year in the Witherspoon Hall, and on the following dates:

October 15, 1909,   "Navigating the Air," Mr. Augustus Post, Secretary Aero Club of America.

November 12, 1909, "Quality of Light," Mr. Paul F. Bauder, Cleveland, Ohio.

December 10, 1909, "Perils of Peace or a Safer America," Wm. H. Tolman, Ph.D., Director of the Museum of Safety and Sanitation, New York.

January 28, 1910,   "Road, Administration and Maintenance," Mr. Logan W. Page, Director Office of Public Roads, Washington, D. C.

February 11, 1910,   "Recent Methods for the Production of Light," Dr. Robert H. Bradbury, Southern Manual High School, Philadelphia, Pa.

March 14, 1910,   "Salvation of Our Trees," Mr. John Davey, Kent, O.

Respectfully submitted,

LAWRENCE T. PAUL,
Chairman.

REPORT OF THE COMMITTEE ON PUBLICATIONS.

To the Board of Managers:

In response to the new impulses which have reinforced the activities of the Institute in general during the past year, its Publication Department has made marked advances during that period. With the co-operation and, to a notable extent, under the lead of the present Secretary of the Institute, the staff of contributors to the pages of the JOURNAL has been largely increased, so that the literary material at the disposal of your Editorial Committee is now not only more than ample in quantity, but also of such scientific value as to fully maintain the high standing of the Institute in this regard. With this enlarged co-operation, the JOURNAL is gaining renewed recognition as a repository of original data in the domain of the applied sciences and bids fair to become again what it was a generation ago, an exponent of the most important advances in Science and the Arts.

The application of the recently established Potts Gold Medal and also of at least two Longstreth Silver Medals as prizes to be awarded for the most important papers published in the JOURNAL during the year falls in line with the efforts of your Publication Committee in this regard. These papers, hitherto accorded some measure of recognition in the form of special

reprints furnished to their authors by the Institute, have in not a few instances merited a more marked distinction, and this the Institute will hereafter be in position to award.

The improvement of the JOURNAL during the past year as regards its contents has extended to its typographic quality as well. The changes in this direction, while thoroughgoing and extensive, have yet been studiously made to retain that general appearance of the JOURNAL which has characterized it throughout its many years and which has thus, in a way, become a symbol of its stability.

The financial status of the JOURNAL has also improved considerably during the past year. Notwithstanding the additional costs of the publication incurred during this period and, to some extent at least, because of these additions, the income of the publication has overlapped the additional costs and brought it more and more nearly to the point where the cash balance will be that of a surplus instead of a deficit. Even as it is, counting the accretions to the Library, obtained through exchanges with the JOURNAL, its publication affords a substantial gain, though not yet enough to reasonably requite the efforts for its promotion. Not the least important of these efforts are those of the Actuary of the Institute, whose co-operation in the management of the business affairs of the Publication Committee is greatly appreciated by its members.

Respectfully submitted,

Louis E. LEVY,
Chairman.

REPORT OF THE COMMITTEE ON SECTIONAL ARRANGEMENTS.

To the Board of Managers:

During the year ending September 30. 1910, thirty-one meetings were held by the Sections and papers on the following subjects were presented:

PHYSICS AND CHEMISTRY SECTION.

Eight Meetings.

October 7, 1909.
Some of the Laws Concerning Voltaic Cells.
Prof. Edward H. Landis.

November 11, 1909.
Advances in Electro-Analysis.
Mr. Jacob S. Goldbaum.

ELECTRICAL SECTION.

Eight Meetings.

October 14, 1909.
Recent Improvements i.. the Design of Nernst Lamps.
Mr. Chas. A. Barton.

November 18, 1909.
The Electric Reduction of Iron Ore.
Dr. Jos. W. Richards.

January 20, 1910.
Promotion of Safety in the Transportation of Explosives and Other Dangerous Articles in the U. S.
Col. B. W. Dunn.

March 3, 1910.
An Analysis of Illumination Requirements in Street Lighting.
Mr. Arthur G. Sweet.

March 10, 1910.
Phenomena of Flocculation and Deflocculation.
Dr. Edward E. Free.

April 7, 1910.
Chemistry of Colloidal Matter.
Dr. Robt. H. Bradbury.

May 5, 1910.
Flax Growing and Linen Manufacturing in the U. S., Present and Future.
Mr. Jas. Wood Pogue.

May 12, 1910.
Recent Progress in the Chemistry of the Sugars.
Mr. Jos. S. Hepburn.

January 13, 1910.
Methods and Results of Electrical Testing.
Dr. Clayton Sharp.

February 10, 1910.
Electrical Heating.
Mr. W. S. Hadaway, Jr.

February 17, 1910.
Electric Railway Signals.
Mr. Carl P. Nachod.

March 24, 1910.
The Electrometallurgy of Steel.
Dr. Jos. W. Richards.

March 31, 1910.
The Electric Vehicle.
Mr. John Meyer.

April 28, 1910.
Magnetic Hysteresis in a Rotating Field.
Dr. Morton G. Lloyd.

Mechanical and Engineering.

Seven Meetings.

October 21, 1909.
Three Centuries of Glass.
Mr. John I. Arbogast.

December 2, 1909.
The Use of Concrete Piles.
Mr. W. F. Hall.

Photographic Section.

Five Meetings.

October 28, 1909.
Demonstration of the New Bausch and Lomb Balopticon for the Projection of Lantern Slides, Opaque Objects and Micro-Slides.
Mr. Arthur H. Thomas.

December 9, 1909.
Infra-Red and Ultra-Violet—a New Departure in Photography.
Dr. Robt. W. Wood.

December 30, 1909.
   Flying, the New Art.
   Mr. Wilbur R. Kimball.

January 6, 1910.
   Steel in Freight Car Construction.
   Mr. C. A. Seley.

February 3, 1910.
   Modern Heavy Guns.
   Mr. Samuel Lichtman.

March 17, 1910.
   A New Pyrometer.
   Mr. Chas. E. Foster.

April 21, 1910.
   Liquid Gas.
   Mr. L. Akesson.

January 27, 1910.
   The Making of Lantern Slides.
   Mr. Chas. R. Pancoast.

February 24, 1910.
   Symposium on Modern Photographic Developers.
   Messrs. John Bartlett, Reuben Haines, Alfred Holden, S. Hudson Chapman.

April 14, 1910.
   Unusual Trees.
   Mr. J. W. Ridpath.
   Photomicrographs in Natural Colors.
   Dr. Henry Leffmann.

MINING AND METALLURGICAL SECTION.

Three Meetings.

November 4, 1909.
   Address of the President of the Section.
   Prof. A. E. Outerbridge, Jr.

December 16, 1909.
   Comparison of Copper and Lead Smelting.
   Mr. Hiram W. Hixon.

May 19, 1910.
   Copper Deposits of Franklin-Adams Counties, Pa.
   Dr. Edgar T. Wherry.

The attendance at these meetings was much better than during previous years, the average attendance being sixty persons.

It is believed that the subjects presented also proved more interesting than those of previous years. The improvement in attendance and general interest was very marked during the closing months of the year, subsequent to the term embraced in this report.

It is believed that a new stimulus would be given to the work of the sections, if arrangements could be effected to promote co-operative action between the local sections of national scientific and technical associations and the several sections of the Institute, and your committee would suggest that the Board would give authority to the Secretary to use his endeavors towards securing such co-operation.

JAMES CHRISTIE,
Chairman.

PHILADELPHIA, PA., January 11, 1911.

REPORT OF THE COMMITTEE ON LIBRARY.

(Abstract)

To The President and Members of The Franklin Institute:

The Committee on Library begs leave to present the following report of the activities of the Library for the past year:

The following additions were made to the library during the year ended September 30, 1910:

Source.	Bd. Vols.	Unb. Vols.	Pamphlets	Maps.
By Gift	232	251	420	1
By Exchange	23	1	..	..
From JOURNAL	30	29	103	.
Binding	716	..	..	..
Chemical Binding Fund...	7	..	..	..
General Appropriation ...	199	30	3	..
Moore Fund	70	4	..	..
Lea Fund	5	2	..	..
Morris Fund	13	..	50	..
Potts Fund	1	..	..	..

Received in the following monthly installments:

Source.	Bd. Vols.	Unb. Vols.	Pamphlets.	Maps.
1909 October	192	16	42	..
November	58	30	50	..
December	162	22	13	..
1910 January	31	30	11	..
February	84	29	44	..
March	65	17	107	..
April	123	27	102	..
May	55	28	41	..
June	224	27	34	..
July	41	35	25	..
August	124	17	47	..
September	137	39	60	1
	1296	317	576	1

Total additions for the year, 2190.

Gifts of books and pamphlets in large quantities or of special importance were received from Messrs. W. E. Gatchell, R. W. Gilpin, C. J. Reed, E. H. Sanborn, W. R. Webster, Drs. S. Solis Cohen and E. J. Houston, Mrs. J. M. Emanuel, The C. J. Toerring Company and the Royal Technical High School of Karlsruhe. Mr. Carl Hering deposited four volumes.

The contents of the Library on October 1, 1910 (after deducting the books transferred to the Free Library), were as follows:

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Volumes bound and unbound................ 60,904
Pamphlets ................................ 47,468
Maps and Charts ..........................  2.267
Drawings, Designs, Lithographs ...........    783
Photographs .............................   1,312
Newspaper Clippings ......................    192
Manuscripts ..............................     34
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Books on deposit, 51.

DUPLICATES.

The following number was added during the year: 111 bound volumes and 300 magazines.

There were sold during the year: 451 bound volumes, 147 unbound volumes, 3 pamphlets, 465 magazines.

BINDING.

The total number of volumes bound during the year was 760, viz.:

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Volumes of periodicals ....................... 665
Recent volumes of British patents.............  51
Chemical periodicals charged to the Chemical
    Periodicals Binding Fund ..................   7
Purchased with the income of the Moore Fund
    and binding charged to that fund...........  10
Bound with the income of the Morris Fund....    1
Old books rebound ............................  25
Old books repaired ...........................   1
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EVENING ATTENDANCE.

The Library was open on 44 evenings during the year until 10 o'clock, namely: On the evenings of the Section Meetings and on the monthly meetings of the Institute.

BUILDING CHANGES.

The routine work of the Library has been somewhat disorganized during the past few months by changes in the various parts of the building, which have greatly benefited the Library.

The files of periodicals which have been stored in the Secretary's Office for many years and those which were distributd throughout the school rooms were all transferred to a room in the basement especially fitted up for the purpose.

The two rooms on the first floor which have been in use for book storage for several years were cleaned out. Most of the books and pamphlets were transferred to the old Journal storeroom on the third floor, the stock of Journals which were formerly kept in this room having been transferred to a room in the basement properly arranged as a stockroom.

The Library Committee desires to express its appreciation of the very considerable improvements which have recently been made both in the extension of the space and addition of many conveniences to the Library.

BINDING OF PAMPHLETS.

By arrangement with a friend of the Institute it has become possible to have the pamphlets on mechanics bound and made accessible to readers. After binding they will form a part of the regular Library. A number of volumes are now at the bindery and others are being made ready. They will form a most valuable addition to the literature on mechanics in the Library and it is hoped that it will be possible to obtain funds which will enable the Committee to bind the pamphlets on other subjects.

PUBLIC DOCUMENTS.

Work on the removal to the Free Library of government documents consisting in all of 4666 bound volumes, 132 unbound volumes, and 34 pamphlets, began September 4, 1909, and was continued throughout the year. The collection of old coast survey charts mounted on 249 boards were also included in the transfer. A number of documents on technical subjects were retained; if it is found on examination of the catalogue that they are already in the Library they will be sent to the Free Library later.

ST. ANDREW'S SOCIETY.

The Library had on its shelves books on Scotland, 30 volumes in all, which have not been consulted for many years. At the suggestion of Mr. Ronaldson, a member of the Committee, they have been deposited with the St. Andrew's Society of Philadelphia and will form a part of the library on Scotland which has recently been established, though the Franklin Institute will still continue to own them.

NEW BOOKS.

At the suggestion of the Secretary the new books purchased from month to month will be displayed in the centre of the reading room where they will be accessible to members without any further formality.

For nearly a year an advertisement has appeared in the Journal from month to month calling attention to the fact that the library staff is prepared to verify references and do copying. No requests have yet been made for this service. The notice is still being continued.

Respectfully submitted,

Geo. F. Stradling,
Chairman, Committee on Library.

REPORT OF THE COMMITTEE ON MEETINGS.

To the President and Members of the Franklin Institute:

Under arrangements made by the Committee on Meetings, with the assistance and co-operation of the Secretary's Office, ten Stated Meetings of the Institute were held during the past year, at which the following subjects were presented:

October Meeting, 1909: "Some of The Lighting Features of The Hudson-Fulton Celebration," by Mr. Arthur Williams.

November Meeting, 1909: "Bakelite and Its Applications," by Dr. Leo H. Baekeland.

December Meeting, 1909: "High-Power Rifle," by Major Franklin Philips.

January Meeting, 1910: "The Dynatak," by Dr. N. M. Hopkins.

February Meeting, 1910: "Development of the Mallet Locomotive," by Mr. Grafton Greenough.

March Meeting, 1910: "The Physical Production of Light," by Dr. Edward P. Hyde.

April Meeting, 1910: "The Waste of Life and Resources in the Mining Industry," by Dr. J. A. Holmes.

May Meeting, 1910: "Some Facts About Electrical Insulation," by Prof. A. J. Rowland.

June Meeting, 1910: "History and Development of Picture Projection," by Mr. F. H. Stewart and Mr. Max Milligan.

September Meeting, 1910: "The Moore Light," by Mr. D. McFarlan Moore.

The attendance at the meetings still continues to grow.

Over two hundred persons attended the June meeting.

This growing appreciation of the standing of the speakers and the value of their addresses is gratifying.

Respectfully submitted,

JAMES S. ROGERS,
January 11, 1911.   *Chairman.*

REPORT OF THE COMMITTEE ON SCIENCE AND THE ARTS.

To the President and Members of the Franklin Institute:

The Committee on Science and the Arts beg to submit the following statement of its operation for the year ending September 30, 1910:

The total number of cases on the records September 30, 1909, was 72; cases added during the year, 16; cases closed, 30; cases pending September 30, 1910, 58. Amendments relating to the recently adopted regulations were considered at various intervals and have been adopted in their final form. Notable among them is the resolution defining the duty of the sub-committee on Literature to examine papers of unusual merit presented in the JOURNAL with a view to recommending the award of the Potts Medal.

A considerable number of pending cases on which no information was available were, at the suggestion of the Committee on Preliminary Examination, dismissed without prejudice.

The Chairman desires to express his deep appreciation of the active and efficient co-operation of his fellow members of the Committee.

Respectfully submitted,

Thomas Spencer,
Chairman.

January 11, 1911.

APPENDIX.

Details of Awards, Etc.

AWARDS OF THE ELLIOTT CRESSON MEDAL.

2432.—Lumiere Color Photography.
2473.—Underwood Typewriter.

AWARD OF THE JOHN SCOTT LEGACY PREMIUMS AND MEDAL.

2457.—Telelectric Company's Piano Player.
2487.—Baekeland's Bakelite.

AWARD OF THE EDWARD LONGSTRETH MEDAL OF MERIT.

2464.—Rushton Trailing Truck for Locomotives.
2465.—Reese Dirigible Balloon.
2463.—Murray's Safety Devices and Protective Appliances for Interior Electric Wiring.

AWARD OF A CERTIFICATE OF MERIT.

2462.—Blanton's Shaft Coupling, Shaft and Hub Connections.

REPORTS MADE ADVISORY.

2442,   2450,   2456,   2468.

CASES STRICKEN OFF THROUGH INSUFFICIENT DATA, ETC.

2243	2270	2275	2288	2290
2356	2390	2398	2414	2415
2434	2438	2444	2451	2452

CASES WITHDRAWN.

2291   2396   2443

PRESENTATION OF ELLIOTT CRESSON MEDAL

TO

JOHN FRITZ, ESQ.

The award by the Franklin Institute of the Elliott Cresson Gold Medal to John Fritz was signalized by its presentation to the venerable ironmaster and inventor on the occasion of a dinner given in his honor by the Manufacturers Club of Philadelphia on Thursday evening, November 17th, ult. The function of making the presentation had been delegated by President Clark of the Institute to former President John Birkinbine, who prefaced his address to the recipient of the medal by a brief review of the tremendous advances which had been made in every direction of human activity during the 88 years of John Fritz's life time, and proceeded to dwell upon the part taken by him in furthering these advances through his work in the development of the iron and steel industries.

In response, Mr. Fritz, reading from manuscript said, in part:

" I appreciate fully this kindly manifestation of your esteem. It gives rise to feelings of emotion, which carry me back to my youth when I was working on the farm from daylight until dark, barefooted, as was the custom at that time, driving the cattle into the yard, milking the cows, feeding or working the oxen. . . . Whatever little I may have accomplished is largely due to the brave and loyal men who so nobly stood by me throughout all the trials and perplexities encountered during my long connection with the iron and steel industries. But, alas, the majority of these loyal associates are gone and the grave has closed over them. Yet they are not forgotten and they shall ever have a green spot in my memory. . . . Much of my success may be attributed to the wonderful progress that has been made in the arts and sciences within this most remarkable century. Having inherited some mechanical ability and being of an investigating turn of mind and disposed to lead rather than to follow, and being possessed of the faculty of drawing able men around me, which is essential at all times to success and more especially at that period, it seemed, in a measure, that I should blend the old and the new. . . .

" While we have properly received great credit for unprecedented developments we have made in the iron and steel industry in the United States, we should not forget that it was the inventions of Cort, of Mushet, of Bessemer, of Siemens, and Thomas that enabled us to accomplish such important results, and to them all civilized nations owe a debt of gratitude for the incomparable blessings their inventions have conferred on society. . . .

" Yet, how few of us, even for a moment, think of the trials, troubles, disappointments, mental anxiety and bodily toil these men underwent in the introduction and perfection of their inventions, besides suffering the sneers and jibes of those who imagined that an inventor was nothing but a wild enthusiast, and treated him accordingly. The story of many inventors is truly pathetic—and none more so than that of the lamented Thomas. The

personal side of the story of the inventor of the basic process can only be appreciated by the reading of his life.

"It is largely to the invention, introduction and perfection of the modern system of steel making in this country that we are indebted for the education of our people in science and in the mechanical and metallurgical arts, which have enabled them to erect such manufacturing plants as were necessary to supply our Government with the sinews of war, making it possible to achieve those glorious victories which at once placed us in the front rank among the nations of the earth."

FRANKLIN INSTITUTE.

(*Proceedings of the Stated Meeting, held Wednesday, January 18, 1911.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 18, 1911.

PRESIDENT WALTON CLARK *in the Chair.*

The annual meeting of the Institute was held this evening at eight o'clock, President Walton Clark in the Chair. The minutes of the special meeting of December 9th and the regular meeting of December 21st were read and approved.

The Tellers, Messrs. Griggs, Colvin and Jennings, submitted the report of the ballots cast for officers and members of the Board of Managers. The following persons were duly declared elected to the respective offices:

President (to serve one year), Walton Clark.

Vice-President (to serve three years), James Christie.

Treasurer (to serve one year), Cyrus Borgner

Managers (to serve three years), John Birkinbine, Walton Forstall, E. Goldsmith, Louis E. Levy, Richard Waln Meirs, Alex. P. Robinson, Coleman Sellers, Jr.

Managers (to serve one year), George A. Hoadley, G. E. Kirkpatrick, Isaac Norris, Jr.

The President presented a statement of the work of the Institute during the past year. Mr. Churchill Hungerford, Filtration Engineer, of Philadelphia, presented a communication on "Water Filtration for Industrial Purposes." The speaker described modern methods of filtration and the plants in operation at various large industrial establishments. The progress made in methods of filtration during the past few years was referred to and the types of filters were shown. The subject was illustrated by a number of lantern slides.

At the close of the paper a vote of thanks was presented to Mr. Hungerford.

On motion the paper was referred to the Committee on Publication.

Adjourned.

R. B. OWENS,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, January 4, 1911.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 4, 1911.

MR. THOMAS SPENCER *in the Chair.*

The following reports were presented for final action:

No. 2474.—Baylis Brush Holder. Certificate of Merit. Adopted.
No. 2476.—Roper Safety Propeller. Laid over until next meeting for further information.
No. 2489.—Hopkins' Speedometer and Dynamometer. On motion referred back to Sub-Committee for further information.

The following report was presented for first reading:

No. 2492.—Ramsden's Devices for Raising Vessels when sunk (Advisory) Adopted.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Physics and Chemistry.—The stated meeting of the Section was held in the Hall of the Institute on Thursday, December 22, 1910, at 8 P.M. with Mr. Alfred Rigling in the Chair. Twenty-five members and visitors were present.

An original paper entitled "The Relation of Certain Non-leguminous Plants to the Nitrate Content of Soil," by Professors T. Lyttleton Lyon and James A. Bizell of the Department of Soil Technology, Cornell University, Ithaca, N. Y., was read by title.

Joseph S. Hepburn, A.M., M.S., Secretary of the Section, delivered an address upon "Recent Progress in the Chemistry of the Terpenes and Camphors," in which was reviewed the work of Wallach upon terpenes, camphors, cyclic ketones and their related compounds. Inversion of the terpene compounds and the occurrence of oxonium derivatives in this series were also discussed. The lecture was illustrated with charts and specimens of the terpenes, camphors and essential oils. A number of lantern slides were shown bearing upon the chemistry and technology of these compounds. The paper was discussed and referred for publication.

A vote of thanks was tendered the speaker, and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Electrical Section.—A meeting of the Section was held on Thursday evening, December 29, 1910, at 8 o'clock. In the absence of the Chairman the meeting was called to order by Dr. E. Goldsmith.

Sixty members and visitors present.

The minutes of the previous meeting were read and approved.

Mr. K. A. Albrecht, Electrical Engineer, of New York City, then presented an interesting communication on Arc Lamps with special reference to flame arcs. The speaker reviewed the subject of the development of the arc light from its experimental stages nearly a century ago and described many of the recent inventions and improvements. The subject was illustrated by models and lantern slides.

After a brief discussion the thanks of the meeting were extended to the speaker. Adjourned.

ALFRED RIGLING,
Acting Secretary.

Electrical Section.—A special meeting of the Section was held on Tuesday, January 3, 1911, at eight o'clock. Present, 175 members and visitors.

Dr. R. B. Owens, the Secretary of the Institute, introduced Mr. E. H. Flanders, Engineer of the Electric Storage Battery Company of Philadelphia, who presented a communication on a new battery for electric vehicles, known commercially as the iron-clad exide battery and recently placed on the market.

The speaker described the construction and action of the iron-clad battery and compared the performance characteristics with those of the exide and other forms of lead batteries and pointed out especially the advantages of the new form for intermittent and vehicle work. The subject was illustrated by lantern slides and complete batteries and parts were shown.

In the discussion which followed the paper Messrs. Forstall, Bartlett, Snyder, Spencer, Ford, Whitney, the chairman, and others participated.

Adjourned.

ALFRED RIGLING,
Acting Secretary.

Section of Physics and Chemistry.—The stated meeting of the Section was held in the Hall of the Institute on Thursday, January 5, 1911, at 8 P.M., with Mr. Alfred Rigling in the Chair. Thirty-eight members and visitors were present.

The minutes of the previous meeting were read and approved.

Professor William A. Pearson, Chemist to the Smith, Kline and French Company, delivered a lecture upon "The Preparation and Testing of Drugs," in which he discussed the manufacture and analytical control of "straight pharmaceuticals" or medicinal preparations made from plants, biological products and chemical compounds. The lecture was illustrated with lantern slides. The paper was discussed by Dr. A. W. Miller and others. On motion of Mr. Henry F. Colvin, a vote of thanks was tendered Professor Pearson.

On motion the meeting adjourned, after having referred the paper to the Committee on Publications.

JOSEPH S. HEPBURN,
Secretary.

Electrical Section.—A meeting of the Section was held on Thursday evening, January 12th, at eight o'clock.

Mr. Thomas Spencer in the Chair.

Present, fifty members and visitors.

The minutes of regular meeting of December 29, 1910, and of the Special Meeting of January 3, 1911, were approved.

The Chairman introduced Mr. G. S. Merrill, Assistant to the Chief Engineer of the National Electric Lamp Association, who read an interesting paper on " New Metallic Filament Lamps.' The physical properties of osmium, tungsten, molybdenum, tantalum, and other filament materials were given consideration. Filament testing and testing apparatus were fully described and numerous results of tests were shown. The subject was illustrated by lantern slides.

In the discussion which followed the paper, Mr. Hering, Dr. Owens, Mr. Greenfield, the Chairman, and others participated.

The thanks of the meeting were extended to the speaker and his paper was referred to the Committee on Publications.

Adjourned.

ALFRED RIGLING,
Acting Secretary.

MEMBERSHIP NOTES.

Élections to Membership.

RESIDENT.

MR. WILLIAM HEILPRIN, manufacturer, 1429 N. Twenty-first Street, Philadelphia.

Changes of Address.

MR. WILLIAM G. ROGERS, 1327 S. Wilton Street, Philadelphia.

MR. HARRY C. DEAN, 108 Cedar Street, Michigan City, Ind.

MR. S. P. WETHERILL, Room 600, Morris Building, Philadelphia.

MR. S. M. VAUCLAIN, in care of Baldwin Locomotive Works, 500 N. Broad Street, Philadelphia.

MR. SAMUEL SHOEMAKER, 1628 New Land Title Bldg., Philadelphia.

MR. ALFRED C. HARRISON, Room 660 Drexel Building, Philadelphia.

MR. R. G. LADOMUS, 1706 N. Broad Street, Philadelphia.

MR. B. DENVER COPPAGE, 14 Willard Street, Wilmington, Del.

MR. J. F. LEVARON, Chardon, Ohio.

MR. W. F. LOYD, 1420 Euclid Ave., Philadelphia.

MR. JOHN G. FELTON, 57 First Ave., Gloversville, N. Y.

NECROLOGY.

MRS. L. S. BARNES, 2200 Pine Street, Philadelphia.

LIBRARY NOTES.

Purchases.

GILL, A. H.—Engine-Room Chemistry.

ZUR NEDDEN, D. F.—Engineering Workshops, Machines and Processes.

PULLEN, N. W. F.—Injectors.

GUNN, J.—The Practical Design of Motor Cars.

ENNIS, W. D.—Applied Thermodynamics for Engineers.

COLLINS, H. E.—Shaft Governors.

COLLINS, H. E.—Erecting Work.

COLLINS, H. E.—Shafting, Pulleys, Belting and Rope Transmission.

COLLINS, H. E.—Pipes and Piping.

COLLINS, H. E.—Boilers.

COLLINS, H. E.—Knocks and Kinks.

COLLINS, H. E.—Steam Turbines.

WOODWORTH, J. V.—Grinding and Lapping Tools, Processes and Fixtures.

WOODWORTH, J. V.—Gages and Gaging Systems.

ARRHENIUS, S.—Worlds in the Making.

CLARKE, J.—Physical Science in the Time of Nero.

LOGNE, C. H.—American Machinist Gear Book.

SINCLAIR, A.—Development of the Locomotive Engine.

Standard Handbook for Electrical Engineers, 1910.

HARRIS, E. G.—Compressed Air.

KENT, WM,—The Mechanical Engineers' Pocket-Book.

GOODRICH, C. L. and STANLEY, F. A.—Automatic Screw Machines and Their Tools.

WEST, P. C. H.—The Modern Manufacture of Portland Cement, vol. i.

JEPSON, G.—Cams and the Principles of Their Construction.

MEES, C. E. K.—The Photographs of Coloured Objects.

SOTHERN, J. W.—The Marine Steam Turbine.

PEIRCE, B. O.—Elements of the Theory of the Newtonian Potential Function.

PENDRED, V.—The Railway Locomotive.

STEINMETZ, C. P.—Engineering Mathematics.

DONALDSON, F.—Practical Shaft Sinking.

HECK, R. C. H.—Notes on Elementary Kinematics.

GOODRICH, C. L., and STANLEY, F. A.—Accurate Tool Work.

MAXWELL, W. H., and BROWN, J. T.—The Encyclopædia of Municipal and Sanitary Engineering.

PEDDLE, J. B.—The Construction of Graphical Charts.

SMITH, F. E.—A Hand-Book of General Instruction for Mechanics.

Gifts.

The art of Distillation: or a treatise of the choicest spagyrical preparations, experiments, and curiosities, performed by way of distillation, together with the description of the choicest furnaces and vessels used by ancient and modern chymists and the anatomy of gold and silver; with the

chiefest preparations and curiosities thereof; together with their vertues. In six books by John French, Dr. in physick. . . . London, 1667. (From Mr. Richard Waln Meirs.)

On the Nature of Things, nine books; written by Philipp Theophrastus of Hohenheim called Paracelsus: The titles of the nine bookes. Of the generations, growths, conservations, life, death, renewing, transmutations, separations, signatures of naturall things. London, 1650. [With this work is bound a copy of "A New Light of Alchymie," by the same author.] (From Mr. Richard Waln Meirs.)

The Hermetical Triumph: or, the victorius philosophical stone. A treatise more compleat and more intelligible than any extant, concerning the hermetical magistery. Translated from the French. To which is added the Ancient War of the knights, . . Translated from the German. London, no date. (From Mr. Richard Waln Meirs.)

Hermippus Redivivus: or, the sage's triumph over old age and the grave Wherein, a method is laid down for prolonging the life and vigour of man. Including, a commentary upon an antient inscription, in which this great secret is revealed; supported by numerous authorities. The second edition. London, 1749. (From Mr. Richard Waln Meirs.)

The magical writings of Thomas Vaughan (Eugenius Philalethes). A verbatim reprint of his first four treatises; anthroposophia, theomagica, anima magica, abscondita, magia adamica, and the true cœlum terræ by Arthur Edward Waite. London, 1888. (From Mr. Richard Waln Meirs.)

The works of the highly experienced and famous chymist, John Rudolph Glauber: containing, great variety of choice secrets in medicine and alchymy in the working of metallick mines, and the separation of metals: also, various cheap and easie ways of making salt-petre, and improving of barren land, and the fruits of the earth. Translated into English, and published for publick good by the labour, care, and charge, of Christopher Packe, Philo-chymico-medicus. London, 1689. (From Mr. Richard Waln Meirs.)

Cincinnati, Ohio, Commissioners of Waterworks. Eighth, ninth, tenth, eleventh and Final Report. Cincinnati, 1904 to 1909. (From the Commissioners.)

Wisconsin State Historical Society. Collections, vol. xix. Madison, 1910. (From the Society.)

New Zealand Mines Department. Papers and reports relating to Minerals and Mining. Wellington, 1910. (From the Department.)

Atlantic Deeper Waterways Association. Report of the proceedings of the Third Annual Convention held at Providence, 1910. Philadelphia, 1910. (From the Hon. J. Hampton Moore.)

American Society of Mechanical Engineers. Transactions, vol. xxxi, 1909. New York, 1910. (From the Society.)

Staffordshire Iron and Steel Institute. Proceedings, vol. xxv, 1909-1910. Stourbridge, 1910. (From the Institute.)

Tonindustrie Kalender 1911, three parts. Berlin, 1910. (From the Tonindustrie Zeitung.)

Liverpool Engineering Society. Transactions, vol. xxxi, 1909–1910. Liverpool, 1910. (From the Society.)

Chief Inspector of Mines of Ohio. Thirty-fifth Annual Report for 1909. Springfield, 1910. (From the Inspector.)

Philadelphia Bureau of Surveys. Report for 1909. Philadelphia, 1910. (From the Bureau.)

California State Mining Bureau. Bulletins No. 54–59 incl. Sacramento, 1909–1910. (From the University of California.)

Harvard University Catalogue for 1910–1911. Cambridge, 1910. (From the University.)

Ontario Department of Agriculture. Report of the Farmers' Institutes for 1909, Part I. Toronto, 1910. (From the Department.)

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Massachusetts Institute of Technology. Catalogue, Dec., 1910. Boston, 1910. (From the Institute.)

Australia Bureau of Census and Statistics. Trade and Customs and Excise Revenue of the Commonwealth for 1909. Melbourne, 1910. (From the Bureau.)

Canada Minister of Public Works. Report for year ending March, 1910. Ottawa, 1910. (From the Dept. of Public Works.)

U. S. Department of Trade and Commerce. Annual Report of the Operations of the Light-House Board for year ending June 30, 1910. Washington, D. C., 1910. (From the Department.)

Canada, Bureau of Mines. Nineteenth Annual Report, part I. Toronto, 1910. (From the Bureau.)

Burroughs Adding Machine Co. Book on " Cost Keeping Short Cuts." Detroit, 1910. (From the Company.)

Missouri Botanical Garden. Twenty-first Annual Report. St. Louis, 1910. (From the Garden.)

Vulcanite Portland Cement Co. Pamphlets on " Concrete in the Country " and " Concrete Surface Finishes." Philadelphia, 1910. (From the Company.)

Maine, Bureau of Industrial and Labor Statistics. Report. Augusta, 1910. (From the Bureau.)

American Railway Master Mechanics' Association. Proceedings, vol. xliii. Chicago, 1910. (From the Association.)

U. S. Library of Congress. Report of the Librarian for year ending June, 1910. Washington, D. C., 1910. (From the Library.)

New York State Museum. Bulletin No. 45 " Geology of the Thousand Islands Region." Albany, 1910. (From the Museum.)

Pennsylvania Railroad Company. Test Department. Bulletin No. 5. Tests
    of an E2A Locomotive, 1910. (From the Pennsylvania R. R. Co.)

Connecticut Bureau of Vital Statistics. Sixty-second Registration Report,
    1909. Hartford, 1910. (From the Bureau.)

Ontario Department of Agriculture. Report of the Women's Institutes,
    Part I. Toronto, 1910. (From the Department.)

Australia Bureau of Census and Statistics. Shipping and Oversea Migra-
    tion for 1909. Melbourne, n. d. (From the Bureau.)

Astronomical and Astrophysical Society of America. Publications, vol. i.
    Ann Arbor, 1910. (From the Society.)

Institution of Civil Engineers. Minutes of the Proceedings, vol. clxxxii.
    London, 1910. (From the Institution.)

U. S. Navy Department. Navy Yearbook, 1910. Washington, D. C., 1910.
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U. S. Navy Department. Report of the Secretary of the Navy. Washington,
    1910. (From the Department.)

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    1910. (From the Department.)

Navy Department. Report of the Paymaster-General. Washington, D. C.,
    1910. (From the Department.)

BOOK NOTICES.

L'ANNUAIRE DU BUREAU DES LONGITUDES POUR L'AN 1911 AVEC DES NOTICES
    SCIENTIFIQUES. Publié par Le Bureau des Longitudes. 750 pages,
    3¾″ x 6″. Paper, 1 fr., 50 net; by mail. 1 fr. .85. Gauthier-Villars,
    Paris, 1910.

As the title indicates, this work is the standard French almanac contain-
ing official data of interest to mariners and astronomers and much other
information of scientific value. The usual appendix at the end of the volume
this year contains an account by M. H. Poincaré of the Conference of the
International Geodetic Association and a contribution by M. G. Bigourdan
on the Eclipse of the Sun of April 17, 1912.

PENROSE'S PICTORIAL ANNUAL. The Process Year-Book, edited by William
    Gamble, 1910–11, vol. 16. London, A. W. Penrose & Co., Ltd. Price,
    in cloth, 7 shillings. American agents, Messrs. Tennant & Ward, New
    York.

The present volume of this well-known annual contains one hundred
and ninety-two pages of text in which are included sixty illustrated articles
by eminent authorities dealing in an interesting manner with important matters
of theory and practice in process work, printing, photography, and allied
trades.

The illustrations in the present volume are more numerous and more beautiful than those in previous issues and show the remarkable improvements and developments which have been made during the year in illustrative methods.

Thirty-five full-page specimens of one, two, three, and four-color plates, several examples of lithographic offset printing in from one to ten colors and many smaller half-tones and engravings serve to make the volume of considerable interest even to those who are in no way connected with the reproductive arts.

PUBLICATIONS RECEIVED.

U. S. Bureau of Mines. Bulletin No. 2. North Dakota Lignite as a fuel for power-plant boilers. By D. T. Randall and Henry Kreisinger. 42 pages, illustrations, plates, 8vo. Washington, Government, 1910.

The End of Darwinism. Not change but persistence is characteristic of life. Every change is essentially a persistence; only what persists can change. An essay by Alfred P. Schultz, M.D., author of " Race or Mongrel," " The Children of Everybody," etc. Monticello, New York, author. Price, in paper, 50 cents.

U. S. Department of Commerce and Labor, Bureau of the Census. Bulletin 109. Thirteenth census of the United States. Population by States and Territories. 7 pages, Q. Washington, Government, 1910.

Qualitative Chemical Analysis from the stand-point of solubilities, ionization and mass action. By J. I. D. Hinds, Ph.D., LL.D., Professor of Chemistry, University of Nashville and Peabody College for Teachers, Nashville, Tenn. 265 pages, 8vo. Easton, Chemical Publishing Co., 1910. Price, in cloth, $2.00.

Canada Department of Mines, Mines Branch. The production of cement, lime, clay products, stone, and other structural materials in Canada during the calendar year 1909. By John McLeish, B. A. 47 pages. Ottawa, Government, 1910.

The Department of Mines of Canada, its organization and its work. By Alfred W. G. Wilson. 12 pages, 8vo. Reprinted from Economic Geology, vol. v, No. 7, October–November, 1910.

U. S. Department of Agriculture, Bureau of Soils. Bulletin No. 74. Chemical nature of soil organic matter. By Oswald Schreiner and Edmund C. Shorey. 48 pages, plate, 8vo. Washington, Government Printing Office, 1910.

U. S. Bureau of Mines, Bulletin No. 5. Washing and coking tests of coal at the fuel-testing plant, Denver, Colo., July 1, 1908, to June 30, 1909. By A. W. Belden, G. R. Delamater, J. W. Groves and K. M. Way. 62 pages, 8vo. Washington, Government, 1910.

U. S. Commissioner of Education. Report for the year ended June 30, 1910, vol. i. 662 pages, 8vo. Washington, Government, 1910.

Leçons sur l'Electricite professées a l'Institut Electrotechnique Monte-
fiore par Eric Girard. Eighth edition, 2 vols., illustrations, 8vo. Paris,
Gauthier-Villars, 1910. Price, in paper, 24 francs.

An Introduction to Thermodynamics for Engineering Students. By John
Mills, Professor of Physics and Electrical Engineering, Colorado College.
136 pages, illustrations, plates, 8vo. Boston, Ginn & Co., n. d.

Relation between Uranium and Radium. V. F. SODDY. (*Phil.
Mag.*, xx, 340.)—Previous experiments showed that the rate of
growth of Ra, in some old solutions of Ur was according to the
square of the time and from this the existence of a long-lived
intermediate parent (ionium) of Ra was deduced. Measurements
made later have not confirmed the rate of growth, and the estimates
are withdrawn; and the results afford data for the calculation of
the minimum period of the supposed product. This minimum period
is deduced to be 35,000 years.

The Electric Furnace. G. ARNOU. (*Rev. Met.*, vii, 1054.)—
The analysis of several steels prepared in the electric furnace are
given, ranging from one containing carbon 0.08 per cent., manganese
0.16, sulphur 0.012, phosphorus 0.008, and silicon 0.10, to one con-
taining carbon 0.87 per cent., manganese 0.31, sulphur 0.01, phos-
phorus 0.005, and silicon 0.37. Attention is called to the low man-
ganese content, to the absence of gases and of oxide, and to the
remarkable homogeneity of the products, which results in a great
malleability when cold and a very great resistance to shock. Details
are given of the mechanical tests such as tension, deflection on bend-
ing, and resistance to the shock of a falling weight, which show the
great superiority of electric steel. With an equal content of carbon,
tungsten, manganese, etc., the initial magnetization was five or six
per cent. greater than in ordinary magnets, while the permanent
magnetism was about the same.

Heat-Treating High-Speed Tools. C. P. BERG. (*Amer. Mach.*,
xxxiii, 45, 872.)—The statements as to the tempering of high-
speed tools generally cover such a wide range of temperatures
that the minimum would leave the tool far below its best hardening
heat, while the maximum, for several brands of steel, would com-
pletely ruin the tool for work, by burning. This article establishes
the relation that exists between the hardening temperature and the
life of high-speed tools, and establishes a guide for the rapidity
of heating while heat-treating, by using heat absorption tests. It
also determines the degree of temperature that gives different steels
the maximum cutting efficiency, the hardness produced and the
results obtained from severe physical tests. This is a valuable
article to those interested.

Wood Distillation.—A report made to the Census Bureau states that there was consumed in the United States during the calendar year 1909 in the industry of wood distillation, 1,265,000 cords of wood, as against 978,000 cords in 1908 and 1,282,000 cords in 1907. The average cost per cord reported for the 1909 consumption was $3.21, which was an increase of 23 cents, or 8 per cent., over that reported for 1908, and of 6 cents, or 2 per cent., over that for 1907. While a substantial increase is noted in that branch of the industry using yellow pine, fir, and other softwoods as material, the revival of activity was more marked in hardwood distillation, due undoubtedly to the material advance in the average value per gallon of wood alcohol over the two preceding years.

HARDWOOD DISTILLATION.

The distillation of hardwoods was reported from 14 States during 1909, while in 1908 and 1907 it was pursued in only 8 States. Michigan, Pennsylvania, and New York, however, continue to be the centres of activity in this branch of the industry. These three States consumed 84 per cent. of the total quantity of hardwoods reported as used during 1909, and contributed, of the total output of each of the three leading products, charcoal, wood alcohol, and gray acetate, 82 per cent., 93 per cent., and 92 per cent., respectively.

While the average value per unit has varied little for most of the products of hardwood distillation during the past three or four years, for alcohol it has fluctuated over a wide range, following the passage of the so-called denatured alcohol law, which became effective January 1, 1907. The average value per gallon reported for crude alcohol manufactured during the calendar year 1906 was 34 cents. In 1907 it dropped to an average of 15 cents, increased to 17 cents during 1908, and reached an average of 24 cents in 1909.

SOFTWOOD DISTILLATION.

The leading product in point of value in softwood distillation during 1909 was turpentine, and Georgia, Florida, and Alabama, ranking among themselves in the order named, contributed together 68 per cent. of the total output of this commodity. While the total number of active establishments was substantially the same in each of the three years, there has been considerable change in the number in operation in the several States. This is due largely to the fact that various methods of softwood distillation have been tried during recent years, some of which have not proven satisfactory, the industry as a whole being still to some extent in an experimental

stage. The use of sawdust and other mill waste as material in 1909 was substantially greater than in any preceding year and the indications are that the industry will develop largely in future in the direction of utilizing this class of material.

THE COMPARATIVE SUMMARY.

Hardwood Distillation.	1909	1908	1907
Number of plants	116	101	100
Material:			
Beech, birch, maple, etc., cords	1,150,000	879,000	1,220,000
Cost	$3,818,000	$2,711,000	$3,825,000
Products:			
Total value	$7,642,000	$5,408,000	$7,661,000
Charcoal, bushels	53,075,000	37,287,000	50,772,000
Value	$3,299,000	$2,645,000	$3,838,000
Crude alcohol, gallons	8,468,000	6,286,000	7,742,000
Value	$2,082,000	$1,084,000	$1,153,000
Gray acetate, pounds	148,769,000	108,099,000	133,375,000
Value	$2,203,000	$1,637,000	$2,566,000
Brown acetate, pounds	2,157,000	1,586,000	8,153,000
Value	$22,000	$13,000	$94,000
Iron acetate, gallons	303,000	263,000	. . . .
Value	$28,000	$25,000	. . . .
Oils, gallons	38,000	58,000	383,000
Value	$3,000	$4,000	$9,000
All other products, value	$5,000	. . . .	. . . .

Softwood Distillation.	1909	1908	1907
Number of plants	31	30	31
Material:			
Total cost	$242,000	$207,000	$211,000
Longleaf pine, cords	100,000	91,000	61,000
Cost	$234,000	$202,000	$211,000
All other, including mill waste, cords	16,000	8,000	1,000
Cost	$8,000	$6,000	$2,000
Products:			
Total value	$687,000	$491,000	$535,000
Turpentine, gallons	683,000	506,000	655,000
Value	$243,000	$166,000	$305,000
Charcoal, bushels	2,403,000	1,996,000	1,158,000
Value	$210,000	$187,000	$102,000
Oil, gallons	323,000	305,000	392,000
Value	$70,000	$56,000	$69,000
Tar, gallons	1,365,000	967,000	761,000
Value	$105,000	$81,000	$58,000
All other products, value	$59,000	$800	. . . .

DIELECTRIC STRESSES

FROM THE MECHANICAL POINT OF VIEW.

BY

W. S. FRANKLIN,

Lehigh University.

THE object of this paper is to discuss dielectric stresses from what may be called the mechanical as distinguished from the atomistic or electronic point of view. The discussion is based on two ideas, namely (*a*) That dielectric break-down occurs at a definite electric field intensity, and (*b*) That the line of dielectric break-down is a conducting path.

The present paper discusses dielectric stresses only insofar as they are modified by variations of inductivity and shapes of metal parts; fatigue effects (and other effects involving time), the peculiar break-down characteristics of very short air gaps, the corona discharge, and so on will be discussed in a second paper which will be based almost wholly upon the electron theory.

The ordinary practical units, ampere, ohm, volt, coulomb, farad, volt-centimetre, volt per centimetre, etc. are used exclusively in this paper.

A familiarity with the condenser is taken for granted. The equation of the condenser is:

$$Q = CE \qquad (1)$$

in which E is the electromotive force applied to the condenser plates, Q is the amount of charge drawn out of one plate and forced into the other plate, C is the capacity of the condenser.

The capacity of a parallel plate condenser with air as the dielectric is

$$C = 884 \times 10^{-16}\frac{a}{x} \qquad (2)$$

in which a is the area of one of the plates (sectional area of the dielectric) in square centimetres, and x is the thickness of the dielectric in centimetres.

To substitute oil or any other dielectric for the air increases the capacity of a condenser in a certain ratio k so that the capacity may then be expressed by the equation

$$C_{farads} = 884 \times 10^{-16}\frac{ka}{x}. \qquad (3)$$

The factor k is called the *inductivity* of the dielectric (also sometimes called *specific capacity* of the dielectric). Thus the inductivity of kerosene is about 2, which means that the capacity of an air condenser is doubled if kerosene is substituted for the air dielectric.

In the following discussion the letter B is used to designate the factor 884×10^{-16}.

GAUSSES THEOREM.

A theorem of fundamental importance in electrostatic theory is as follows: The total electric flux ϕ emanating from a charged body is equal to $Q \div B$, or the total charge on a body is equal to $B\phi$, where Q is the charge in coulombs and ϕ is electric flux expressed in volt-centimetres in air. (An electric field intensity is expressed in volts per centimetre, and the product of this field intensity by an area in square centimetres gives electric flux in volt-centimetres, the area being perpendicular to the field.)

When applied to a parallel-plate air condenser, Gausses theorem may be derived by multiplying both members of equation (2) by E (the electromotive force between the plates), giving:

$$CE = Q_{coulombs} = Ba\frac{E}{x}$$

but $E \div x$ is the electric field intensity between the plates in volts per centimetre, so that $a \times E \div x$ is the electric flux from

plate to plate in volt-centimetres and therefore, $a \times E \div x = \phi$ whence we have

$$Q = B\phi \qquad (4)$$

Gausses theorem may be derived for a parallel plate condenser with any dielectric by multiplying both members of equation (3) by E (the electromotive force between the plates), giving:

$$CE = Q = B \cdot a \cdot k\frac{E}{x}$$

but $E \div x$ is, as before, the electric field intensity between the plates and $k \times E \div x$ may be defined as the *electric flux density* in the dielectric, so that $a \times kE \div x$ is the total flux, and we thus arrive again at equation (4).

MAGNETIC AND ELECTRIC PARALLEL.

$$B = \mu H$$

Where H is intensity of magnetic field in gausses, μ is the permeability of the medium, and B is the magnetic flux density.

$$F = kf$$

Where f is intensity of electric field in volts per centimetre ($E \div x$), k is the inductivity of the medium, and F is the electric flux density in volt-centimetres per square centimetre.

ELECTRICAL STRESS AND MECHANICAL STRESS.

The stretching force per unit of sectional area of a rod is called the *stress* on the rod, and the elongation of unit length of the rod is called the *strain;* and the strain is proportional to the stress. That is

strain=constant $\times$ stress.

This constant is the reciprocal of what is usually called the modulus of elasticity, and it is large in value for a substance like rubber which is greatly stretched by a moderate stress.

The intensity of an electric field in volts per centimetre (or the volts per centimetre in a layer of dielectric between metal plates) is frequently called *electrical stress,* and the electric flux density kf in the dielectric is frequently called the *electrical strain.* Therefore we have

electrical strain $= k \times$ *electrical stress.*

The inductivity of a dielectric is analogous to an elastic constant (reciprocal of what is called modulus of elasticity). The product kf, which we call electric flux density or electric strain, was called *dielectric polarization* by Maxwell.

In some cases electric flux density (or strain) is given instead of electrical field intensity (or stress) when it is desired to specify the condition of a dielectric. Now electric flux can be expressed in coulombs according to equation (4), B being a numerical factor. Therefore electric flux density (or strain) may be expressed in coulombs per unit area. Thus electric strain is sometimes expressed in coulombs per square inch.[1]

ELECTRIC STRESSES IN PLANE LAYERS OF DIFFERENT DIELECTRICS.

Consider two metal plates with equal thicknesses of air ($k = 1$) and of glass ($k = 6$) between them as shown in Fig. 1. The thing which is constant throughout the region between the metal plates, that is, the thing which has the same value in glass and air is electric flux density kf, because there are equal and opposite charges on two plates, and, therefore according to Gausses theorem the total flux passing out from the positively charged plate ($+ Q$) is equal to the total flux passing in towards the negatively charged plate ($- Q$). Now since kf is the same in the glass and in the air, and since $k = 1$ for air and $k = 6$ for glass, therefore electric field intensity or stress in volts per centimetre (f) is six times as great in the air as in the glass.

Consider the special case in which the glass and air are of equal thickness as indicated in Fig. 1. Then six-sevenths of the battery voltage is impressed on the air layer and one-seventh on the glass layer. If glass and air are each 1 centimetre thick, and if the total voltage is 35,000 volts, then, assuming the air not to break down, the voltage across the air will be 30,000 volts, and the voltage across the glass will be 5000 volts.

If the glass plate is removed, leaving 2 centemetres of air, then the electrical stress on the air will be 17,500 volts per centimetre. Therefore the electrical stress in the air between two plates 2 centimetres apart is increased from 17,500 volts per centimetre to 30,000 volts per centimetre by filling half of the space between the plates with glass of inductivity 6.

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[1] In a recent paper before the American Institute of Electrical engineers an author states that this method of specifying electrical strain is so little understood that he deems it justifyable to give a full discussion of the matter, and he arrives by a confused argument to the wrong result "coulombs per inch cube."

This effect can be shown in a very beautiful manner by con-
necting two metal plates to a high-voltage transformer and
adjusting the plates to a distance such that the intervening air
layer is barely sufficient to sustain the voltage. Then if a glass
plate be introduced between the metal plates, the electrical stress
in the remaining air will be increased sufficiently to break the
air down at each reversal of the alternating voltage, as shown
by the bluish luminosity of the air layer.

The above discussion of the stresses in layers of glass and
air as based on Fig. 1 can be simplified as follows: Imagine a
thin sheet of metal $m\ m$ to be placed between the air and glass
as shown in Fig. 2. We thus have two exactly similar conden-
sers, C' and $C,$ of glass and air, and the capacity of the glass
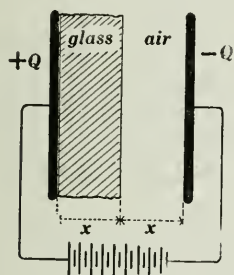
FIG. 1.   FIG. 2.
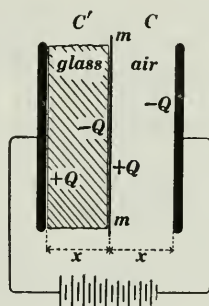
condenser is six times as great as the capacity of the air con-
denser, according to equations (2) and (3). But the charges
on C' and C are the same because they have been charged in
series. Therefore the voltage across the glass condenser is one-
sixth of the voltage across the air condenser, according to equa-
tion (1).

The concentration of the greater part of the voltage upon
the air layer in Figs. 1 and 2 is exactly analogous to the con-
centration of the greater part of the magnetomotive force of a
dynamo field-winding upon the air gap in the magnetic circuit;
only a small portion of the magnetomotive force is required to
force the magnetic flux through the highly permeable iron, and
a large portion of the magnetomotive force is required to force

the magnetic flux through the less permeable air layer. A small
portion of the battery voltage is required to force the electric
flux through the highly inductive glass in Fig. 1 and a large
portion of the voltage is required to force the electric flux
through the less inductive air.

MECHANICAL ANALOG OF FIG 1.

A difficulty in obtaining a simple mechanical idea of the con-
contration of the greater part of the battery voltage on the
air layer in Fig. 1 arises from the following fact: the glass and
the air are *in series* in Fig. 1 (and the electric flux density or
electric strain or yield, in the two is the same), whereas two
mechanical elements have the same *stress* when they are in

FIG. 3.   FIG. 4.
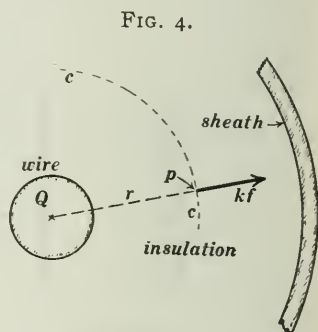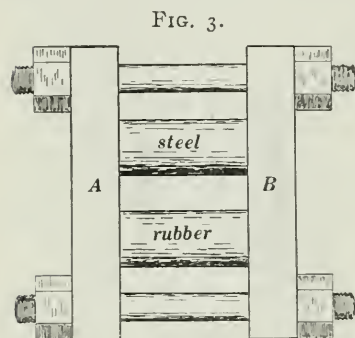
series; to have the same strain or yield, two mechanical elements
must be *in parallel.* Thus Fig. 3 shows a column of steel and a
column of rubber equally compressed between two bars *A* and
B (the steel and rubber columns are in parallel); the easily yield-
ing rubber (high inductivity) supports a small part of the com-
pressing force, and the stiff steel (low inductivity) supports a
large part of the compressing force.

THE GRADED CABLE INSULATION.

Influence of Variation of Inductivity on Electrical Stress.—
Consider unit length of the wire core of a cable and let Q be
the amount of electric charge thereon. Let f be the electric field
intensity in volts per centimetre at the point p in the insulation

distant r from the axis of the cable and let k be the inductivity of the insulating material at p. Then kf (see Fig. 4) is the electric flux density at p, and $2\pi r \times kf$ is the flux across the cylindrical surface cc (of unit length), that is $2\pi rkf$ is the flux emanating from Q, and, therefore, according, to equation (4), we have

$$Q = B \times 2\pi rkf$$

or

$$f = \frac{Q}{2\pi B} \quad \cdot \quad \frac{1}{rk}. \tag{5}$$

Therefore, if k decreases as r increases so that the product rk is constant, then the electrical stress f, in volts per centimetre, will be the same in value throughout the cable insulation.

There is an interesting mechanical analogy to the graded cable insulation. If a thick walled steel tube is subjected to internal pressure as in a cannon, the material next the bore is stretched to its stress-limit before the outer portions of the steel are brought into full action. If easily yielding (high elastic like rubber) steel could be used for the inner portions of the gun tube, then the greater yield of the inner material would tend to bring all of the material of the tube up to the limiting stress simultaneously. There is in fact but little variation in the elastic coefficient of various kinds of steel, and this method of gun construction in therefore impracticable. There are, however, great differences in the inductivities of different insulating materials, and therefore the grading of cable insulation is to some extent practicable.

EXPERIMENTAL EFFECTS DEPENDENT UPON INDUCTIVITY.

The lines of force in an electric field converge upon and pass through a glass rod (high inductivity), and the lines of force in a magnetic field converge upon and pass through an iron rod (high permeability). A glass rod suspended in an electric field oscillates to and fro through an equilibrium position parallel to the field in the same way that a suspended iron rod oscillates in a magnetic field. (Figs. 5 and 6.)

A glass plate is drawn into the intense electric field between

positively charged metal plates in the same way that a piece of iron is drawn into the intense magnetic field between two opposite magnet poles as shown in Figs. 7 and 8. In the same way oil and especially water is drawn into the most intense part of an electric field.

A thin glass cell partly filled with oil and provided with metal terminals A and B is placed in a lantern and the terminals A and B are connected to a Toepler-Holtz machine, as indicated

Fig. 5.
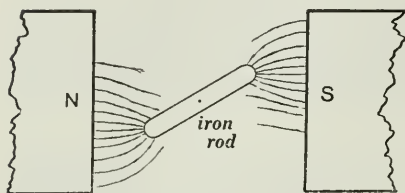
Fig. 6.
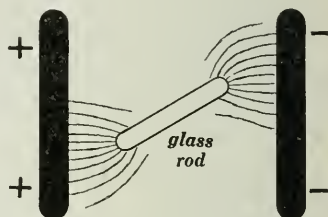
Fig. 7.
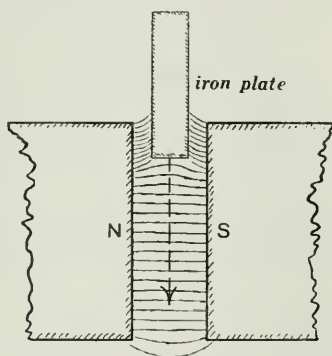
Fig. 8.
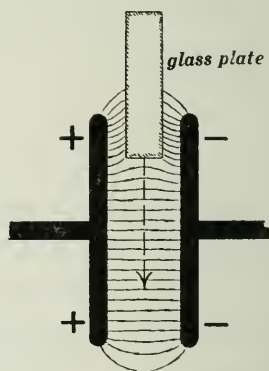
in Fig. 9. The oil (high inductivity) is drawn up as shown, and eventually a column of oil is formed reaching up to terminal A. In the same way a magnetic liquid (permeability greater than unity) would be drawn up to a magnet pole.

Bubbles of air rising in oil in front of a blunt metal terminal (charged) are repelled.

A gold-leaf electoscope is placed in a lantern, and the plate of the electroscope is connected by a fine wire to an insulated plate PP on the lecture table, as shown in Fig. 10.   When a slab of paraffin wax W is placed in the region CC, the electroscope leaves fall slightly.   The capacity of the condenser CC has been increased by the paraffin slab and a greater portion of the charge on the insulated system flows into PP thus decreasing the charge on the electroscope leaves.   If one had two inflated rubber bags connected by a tube, and if one were to make the walls of one bag more yielding by dissolving off a portion of the rubber (if that were possible), then the weakened

Fig. 9.
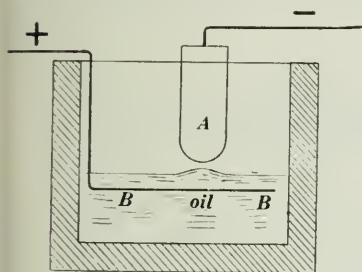
Fig. 10.
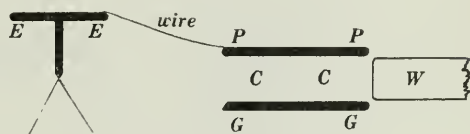
bag would swell and the other bag would shrink.   The plate of paraffin makes the dielectric around PP more yielding and some charge flows from EE into PP.

DIELECTRIC HYSTERESIS.

The most prominent kind of dielectric hysteresis is a kind which is closely analogous to what is technically called *elastic lag* in mechanics.   Glass, for example, when subjected to a mechanical stress takes on a certain amount of strain (deformation) quickly, after which the strain slowly increases for a time; and when the stress is removed, a remnant of the strain persists for a time.   This kind of hysteresis is sometimes called *viscous hysteresis,* and it is very different from the magnetic hysteresis in iron or steel, although a slight amount of viscous hysteresis does exist in very soft iron.

Dielectric hysteresis of the viscous type has long been known to exist, and it is the cause of the so-called " residual charge " which accumulates in a Leyden jar when the jar is completely discharged and allowed to stand.

A Leyden jar is charged. The coatings of the jar are then momentarily connected by wire, and then the jar is left standing on open circuit. After a time the coatings are again connected and a second slight discharge is obtained.
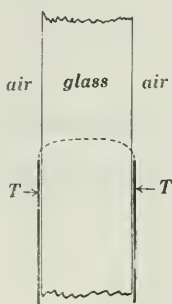
A rubber tube is stretched. This stretch corresponds to the electrical strain of the glass walls of the Leyden jar. The end of the tube is momentarily released, and the end is then clamped fast in what seems to be its equilibrium position. After a time the end is again released and a second slight "discharge " or movement takes place.

FIG. 11.

FIG. 12.

lines of stress
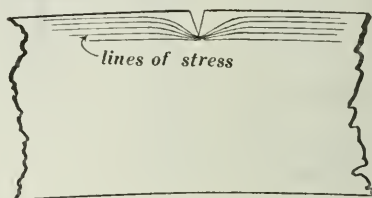
GLEITFUNKEN.

Everyone who has used Leyden jars is familiar with the fact that a spark will often jump seven or eight inches over the edge of a jar from tin-foil to tin-foil, when the coatings are connected to a spark-gap of an inch or an inch and a half. A surface of contract of two dielectrics of different inductivities is electrically very weak even when it is free from dirt and dust. The explanation of this fact for the simple case of the Leyden jar is as follows: Consider the dotted line in Fig. 11 (a tube of electric flux) partly in air and partly in glass. The voltage between the tin-foil coatings is concentrated in the air portions of the tube of flux because of the high inductivity of the glass, and the air portions break down. Tubes of flux then pass between the charged fringes beyond the edges of the tin-foil, and the action is repeated, and so on, until a spark jumps over

the edge of the jar. A strip of window glass placed edgewise in the spark-gap of a Toepler-Holtz machine causes a spark to jump 1½ or 2 inches when a 1-inch spark-gap (without a glass strip) is connected in parallel with the spark-gap of the machine.

CONCENTRATION OF ELECTRICAL STRESSES BY POINTS.

The ease with which a bar of hard tool-steel can be broken when a sharp-bottomed nick is made in one side of the bar is well known. Fig. 12 shows the lines of stress passing around the bottom of a sharp groove in a bent bar. The stress is very greatly concentrated near the bottom of the groove, and the grooves deepens by the formation of a crack. The stress is then

FIG. 13.
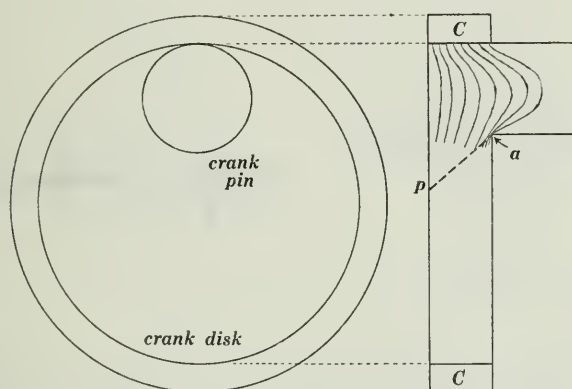
concentrated at the edge of the crack, and the crack is extended farther and farther until the bar is broken in two.

It is perhaps not universally known that the glass-cutting diamond does not make a scratch. Such a scratch would be a shallow flat-bottomed groove, and no very great concentration of stress would occur at the bottom of such a groove when the pane of glass is slightly bent. The end of a cutting diamond is a perfectly rounded " corner " of a natural diamond crystal (the diamond is a crystal with curved faces), and when a cutting diamond is drawn properly across a pane of glass a minute crack is formed under the diamond on account of the excessive

local compression. This crack causes a very great concentration of stress when the pane of glass is subjected to a very slight bending action, and the result is that the crack runs through the pane. When a diamond is drawn heavily across a pane of glass a very considerable exertion is required to break the glass and the crack does not always follow the groove. When a diamond is drawn properly across a pane of glass a very slight bending movement is required to break the glass, and the break nearly always follows the minute crack produced by the diamond.

A very interesting accident occurred at the Bethlehem Steel Works a number of years ago when an attempt was made to strengthen a crank-disk by shrinking a collar upon it. The disk had a crank-pin on one side, and the disk sheared off along the

FIG. 14.
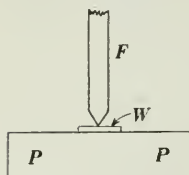
FIG. 15.
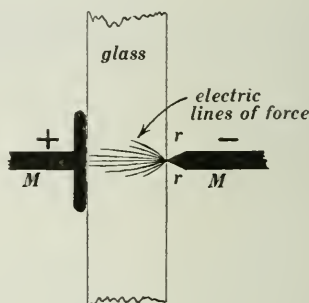
dotted line ap in Fig. 13 on account of the excessive concentration of stress at the reëntrant angle a. The fine curved lines show the approximate trend of the stress lines in the disk due to the collar CC.

An interesting experiment is to place a small piece of window glass on a flat plate of steel (or plate glass) and press a sharp-pointed file against it as shown in Fig 14. The stresses in the window glass are very greatly concentrated at the sharp point of the file, and it takes but little force on the file to break the glass to pieces. If, however, a bit of soft copper is placed under the point of the file, one cannot push hard enough to break the glass; the copper yields (breaks down mechanically) and distributes the stress.

When a voltage is applied to the metal terminals *MM* in
Fig. 15, the electric lines of force (the electrical stress lines)
converge upon the sharp metal point and the electrical stress
is very greatly concentrated near the point. Indeed a compara-
tively low voltage will rupture the glass plate in Fig. 15 because
of the starting of an electric rupture by the excessive concentra-
tion of the stress near the metal point. To produce this result,
however, the region *rr* must be filled with a substance of great
dielectric strength like turpentine or wax. If the region *rr*
is filled with a substance of low dielectric strength like air, the
portion in the immediate neighborhood of the metal point breaks
down electrically and becomes a conductor, and the resultant

FIG. 16.
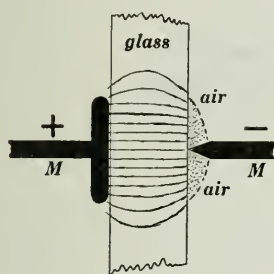
FIG. 17.
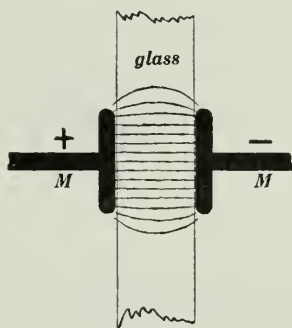
distibution of electrical stress in the glass plate (which is shown
in Fig. 16) is the same as if the glass plate were between two
flat metal plates as shown in Fig. 17. Under these conditions
the electrical stress in the glass is nearly uniform, and a very
high voltage is required to puncture the glass plate because there
is no region of concentrated stress to start the electrical break-
down.

Having air around the metal point in Fig. 15 is like having
a bed of soft copper around the point of the file in Fig. 14.
The copper breaks down mechanically and distributes the stress,
thus preventing excessive concentration of stress near the point
of the file and the starting of a crack thereby. The air breaks
down electrically and distributes the stress, thus preventing ex-

cessive concentration of stress near the metal point and the starting of an electric puncture thereby.

An electrical breakdown in a solid dielectric (and usually in liquid and gaseous dielectrics also) is always in the form of a puncture, that is the breakdown occurs along a line; and this line of breakdown is an electrical conductor. Therefore the electrical stresses in the dielectric are concentrated at the end of an incipient puncture, as at a metal point, and the puncture is thus carried through the dielectric or into regions where the electrical stresses were far below the breakdown value before the puncture started. These details were first definitely studied by Jean [2] in 1858; in describing his results, however, Jean does not of course use the language of mechanical analogy which is here employed.

FIG. 18.
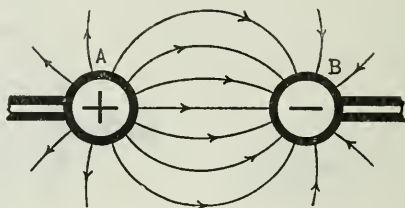
Figure 18 [3] shows the electric lines of force between two metal balls, and Fig. 19 shows how the electric lines of force rearrange themselves when an electric puncture starts.

The voltage required to puncture a homogeneous layer of dielectric is very nearly proportional to the thickness of the layer when the electrodes are flat metal plates as shown in Fig. 17; but the concentration of stress near metal balls as shown in Fig. 18 and near a metal point as shown in Fig. 15 introduces a complication, the sparking voltage is far from being proportional to the thickness of the dielectric between balls or points.

Many dielectrics are very heterogeneous, containing moisture in the interior, for example, and the voltage required to rupture

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[2] Compt. rend., xlvi, 186, 1858.

[3] Figures 18 and 19 are taken from Nichols and Franklin's "Elements of Physics," vol. ii (Electricity and Magnetism). The Macmillan Company, 1896.

such a dielectric between flat plates is far from being proportional to the thickness.

For very small sparking distances in air at normal atmospheric pressure the breakdown stress in volts per centimetre becomes very great. That is, the proportional relation between

FIG. 19.
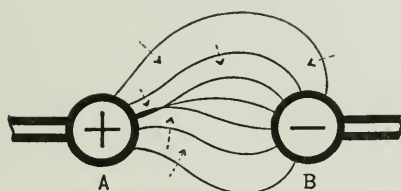
voltage and sparking distance does not hold for very short spark gaps in air and perhaps the same thing is true of liquid and solid dielectrics. The peculiar breakdown characteristics of short air gaps will be considered in a second paper in which the electron theory will be prominently used.

Production of Secondary Metals in 1909. J. P. DUNLOP.—
The United States Geological Survey's figures of recovery of " secondary " copper, lead, zinc, tin, and antimony in 1909 are summarized below in the accompanying table. The secondary metals include those recovered from scrap metal, sweepings, drosses, etc. They are called " secondary " to distinguish them from the metals derived from ore, which are known as " primary " metals.

The following table gives the quantity and value of each secondary metal recovered during the years 1907, 1908, and 1909. The large increase shown in 1909 was occasioned partly by increased business activity and the growing tendency toward conservation, but is explained in part by the fact that the Survey made a more extensive canvass of the sources of production. Many manufacturers who formerly sold their scrap metal, sweepings, skimmings, and drosses now treat them in their own plants. The economic importance of the recovery and use of metal products from scrap metal, etc., is best emphasized by the figures given in the table, and if approximate data could be presented giving the value of the precious metals and of the large quantities of old iron and steel reused the immense value of secondary metals would be even more impressive. As these secondary metals displace equal quantities of primary metal in supplying consumption, they un-

doubtedly affect the prices of primary metals to some extent now and will affect them even more in the future.

The production of secondary copper (including that in brass) was equal to 6.4 per cent. of the total quantity of copper derived from ore in 1909. The secondary lead equalled more than 9 per cent. of the refined lead produced in the United States in 1909. The secondary zinc (including that in brass) equalled 16.5 per cent. of the total production of primary spelter. As there was no reported production in 1909 of antimony from domestic ores and only an insignificant quantity of tin, the secondary recoveries were the only domestic source of supply. The secondary antimony reported was about 25 per cent. of that imported as metal, exclusive of type metal and other antimony alloys or contained in antimony or antimonial lead ores. The secondary tin recovered has increased from 1562 tons in 1907 to 5515 tons in 1909 and now equals 11 per cent. of the total imports of tin into the United States.

Nearly all the establishments making secondary recoveries are in Eastern and Northern States, for it is not the old-junk man who supplies the larger quantity of old and waste metal but the larger manufacturing plants and railways.

PRODUCTION OF SECONDARY METALS IN THE UNITED STATES IN 1907–1909.

Metals.	1907		1908		1909	
	Short tons.	Value.	Short tons.	Value.	Short tons.	Value.
Secondary copper, including that in alloys other than brass	30,240	$11,188,800	11,500	$3,036,000	25,396	$6,602,960
Remelted brass	(a)	....	(a)	....	27,347	5,863,181
Secondary lead	9,990	} 2,702,788	7,990	} 1,556,772	17,822	} 3,538,814
Recovered lead in alloys	15,508		10,543		23,327	
Secondary spelter	18,841	2,390,444	16,970	} 1,657,690	33,040	} 3,695,868
Recovered zinc in alloys other than brass	1,417		665		1,181	
Secondary tin	93	} 914,404	1,124	} 1,641,476	2,423	} 3,281,425
Recovered tin in alloys	1,569		1,666		3,092	
Secondary antimony	(a)	....	(a)	....	27	} 257,362
Recovered antimony in alloys	....	....	....	....	1,529	
Total value	....	17,196,436	....	7,891,938	....	23,239,610

a Statistics not collected.

The Physical Meaning of Entropy. A. L. MENZIN. (*Eng. News*, lxiv, 229.)—The general definition is: In the conversion of heat into work, whether of heat external to a working substance, or contained within it as intrinsic energy, entropy is the minimum unavoidable waste per degree of the absolute temperature at which all of this waste may be rejected by the working substance.

WATER FILTRATION FOR INDUSTRIAL PURPOSES.

BY

CHURCHILL HUNGERFORD,

Filtration Engineer.

It is frequently a matter of surprise to otherwise well in-
formed persons that the ordinary standards of purity required
in drinking water are sometimes not nearly as severe as those
required in water used for industrial purposes. Nevertheless,
this is true in many instances, because the water contains cer-
tain substances which are perfectly harmless to the human sys-
tem but possess chemical affinities for other substances used
in the arts and industries that create very annoying disturbances
indeed. On the other hand, many waters that have been so
highly contaminated by sewage and industrial wastes that no
form of purification would make them suitable for drinking pur-
poses, can be made eminently satisfactory for industrial purposes.
It is a by no means uncommon condition to find a manufactory
unable to use the city supply, which may be justly considered
especially fine from a potable stand-point, yet by means of an
efficient purification plant be able to get perfect satisfaction
from a polluted stream which receives the sewage and industrial
waste of the town itself.

Disregarding the hardness of the water, the reduction of which
is not properly a function of filtration, there are a number of
apparently harmless forms of pollution that are very trouble-
some in many instances.

The writer has in mind a rather remarkable case in a New
York village of a manufactory wherein very gorgeously printed
lap robes are made. This concern has been in business a great
many years and the designs, which are quite ornate and many
colored, are hand printed by large wooden blocks with certain
colors imported from England supposed to be secret mixtures.
These colors are all mordanted with alum. In fact, the robes
themselves are passed through quite a strong solution of alum
at one period of their manufacture, and are then dried. They are

finally washed, and at this point the trouble manifests itself in a rather singular manner. As soon as the water commences to get warm, or during the latter part of May, the light colors commence to get flat and as the season progresses and hot weather comes on, much of the detail is altogether lost and the whites and light shades commence to assume a yellowish cast. The wise men of the block printers shake their heads and say their secret colors are effected by the warm water and as a result robes of a dark shade only can be made during the warm weather.

An investigation of the water supply elicited the information that the major part of it is derived from a shallow lake about seven miles back in the country. The elevation of the water in this lake had been raised four or five feet a number of years ago and overflows a peat-bog over a square mile in extent. During the winter it is customary to close the outlet of this lake and allow it to fill up. About the latter part of May, when the water in the stream begins to get low the gates are opened and the highly colored water from the lake takes the place of the comparatively clear flow. When this colored water reaches the mill and the alum saturated lap robes are washed in it, the coloring matter derived from the peat is precipitated by the alum upon the fibre, and the more color there is to the water the greater the discoloration of the goods. Moreover, the drainage area of the lake being comparatively small and the drain upon the lake heavy the water keeps getting lower and lower until part of the peat-bog is exposed and the water percolating from this causes the lake supply to grow continually darker until the fall rains refill the lake. It can be seen by this that the color of the water and not the temperature is entirely responsible for the apparently bad behavior of the dyes. The above is a harmless but not too attractive city supply.

Another instance is in a city of some 60,000 inhabitants supplied from a fairly large stream. The water from this stream possesses considerable color and is filtered by means of a mechanical filter plant. This mechanical filter plant is very well operated indeed, shows a very high bacterial efficiency and is ideal in every particular save one, and that is that for some reason or other a small amount of hydrate of alumina, formed

during the chemical treatment of the water with alum, finds its way through the filters. This has no hygienic significance whatever and the inhabitants of the town are enthusiastic over the many virtues of their filter plant insofar as the potability and appearance of the water is concerned. However, there are a number of large silk dye-works in this town and this trace of hydrate of alumina present in the water prohibits its use in silk dyeing. Most of the dye houses are located along the banks of the same stream from which the city supply is drawn but at a point below town. The stream at this point is not only badly contaminated with sewage but the discharge from the silk dye houses themselves enters into it making the general color of the water blue-black. Nevertheless, the silk dyers have solved the problem of water supply by filtering this badly contaminated water with a filter which will not permit hydrate of alumina to pass through it. The filtered water is, of course, crystal clear and entirely free from dye.

Still again the anæmic person who spends some weeks at a high-priced sanitarium drinking chalybeate waters with the hope of bringing the iron content of his system up to the normal 26 or 27 grammes which it should contain would probably be quite indignant if told that the water he is drinking in such quantities is not even fit for laundry purposes.

Originally filtration for industrial purposes meant the removal of clay, silt, and vegetable stains from the water. The problem at that time was a simple one as it merely meant that enough alum or sulphate of alumina or similar coagulant was employed as a preliminary treatment, after which the water could be passed through the filters and would be suitable for industrial purposes.

However, as the country became more populated, its manufactories larger and more numerous, the streams commenced to show considerable quantities of various forms of industrial wastes and sewage. The industrial wastes consisted very largely of dyestuffs, waste liquors from paper and pulp mills, chemical wastes from wire-drawing plants, gas-house liquors, tannery wastes, etc. Some streams contained only one or two different varieties of contamination while others contained several. This condition has increased with the population until most of the

streams in the East are greatly discolored and are badly pol-
luted with sewage. Moreover, most of the available sources of
pure water have been preëmpted by municipalities for their
water supplies.

Cheap water is imperative in the present day to the manu-
facturer. He cannot afford to pay from four to thirty-five cents
per thousand gallons to the municipality for several million gal-
lons of water per day and he is perforce driven to the polluted
streams, his only alternative being to place his establishment at
so remote a point that it becomes difficult of access and almost
impossible to procure labor. Naturally he chooses the situa-
tion of his plant with reference to the availability of labor and
the propinquity of the market. The vital question that then
comes before him is, can the highly polluted water supply which
is available be made suitable for his purposes? The answer
to this question, in ninety-nine cases out of one hundred, is in the
affirmative. It can be done and done well. Moreover, in large
plants the average cost of treatment can be kept well below
$3.50 per million gallons, or say one-third of one cent per thou-
sand gallons as against the four to thirty-five cents per thou-
sand the manufacturer would be compelled to pay to the munici-
pality.

Such conditions as the last represent perhaps seventy-five per
cent. of the problems of industrial filtration at the present day
and the percentage is continually increasing.

The problems involved in such waters, especially when con-
taminated by many different substances, become complex in
their nature. True, the old stand-by sulphate of alumina, still
figures very extensively in all such plants, but there are many
conditions wherein the use of sulphate of alumina alone as a
preliminary treatment leads to a downright failure of the filter
plant to accomplish the desired aims. To reach perfect results
an intimate knowledge of the nature of the contamination must
be reached. Chemical analysis, of course, tells us much and
a bacteriological analysis is also necessary in some cases but an
actual survey of the conditions to be met must be made before
an intelligent purification plant can be constructed.

In making this survey it is necessary, particularly on a com-
paratively small stream, to notice the particular hours at which

certain industries discharge the most waste; to note the particular character of the most important of these wastes and to further note very particularly the influence that one set of industrial wastes will have upon another. For instance, the waste dye from a woolen mill mingling with the waste soap from the fulling and finishing department eventually come into contact with the lime existing in the water with the result that not only the soap is precipitated but a very considerable portion of the coloring matter is also carried down. Further down stream we may strike the waste from a wire drawing works or similar industry wherein sulphate of iron enters the water. This combines very actively with the coloring matter and forms a heavy precipitation. At the same time large quantities of domestic sewage are being discharged into the stream. This commences to ferment very rapidly. Portions of it are liquified and other portions precipitated. Bacteria become very active in the stream unless some poisonous or antiseptic substance is being discharged in it. By the time the water has reached the consumer possibly as high as seventy-five per cent. of the dissolved matter that had been discharged into the stream is delivered in a precipitated form, thereby lessening the load on the purification plant by that amount.

Now after having considered all of these points we come to the operation of the plant itself. In the first place we wish to get rid of the already precipitated matter as economically and as efficiently as possible. In the next place we must precipitate as cheaply as possible the remaining deleterious substances. As above stated the most economical and effective substance for doing the major part of this work is sulphate of alumina. The writer realizes that there will be considerable protest made in favor of sulphate of iron and lime. Nevertheless so far as his own experience goes, and, in fact, the experience of some others, sulphate of alumina is cheaper, safer, more satisfactory and far easier to apply than sulphate of iron and lime.

Having applied the sulphate of alumina with a due regard for the alkalinity of the water as evinced by the chemical analysis, the treated water is allowed to flow slowly through a settling tank. The period of time occupied in sedimentation varies greatly with different waters. In some cases one and one-

half hours may be sufficient. In others three hours. Occasionally twelve hours are required, and we know of one instance in which six days' sedimentation is employed. In the latter instance chemicals are not used, the biological conversion of the organic matter being aimed at. Generally speaking, however, three hours' sedimentation wtih aluminum sulphate for a coagulant is sufficient.

We occasionally find, however, upon operating a plant that complete decoloration of the water is not effected and that there is a very offensive odor. Moreover, strange things are taking place in the settling basin. As we look at it we see large masses of sediment rise from the depths, come to the surface, spread out and disappear. One point in the sedimentation basin will show a fairly good degree of sedimentation while further along where sedimentation ought to be further advanced we find the water far more turbid than when first introduced into the basin. The sewage in the water is simply fermenting and this fermentation is not only interfering with sedimentation by reason of the gases evolved but is producing resolution of the impurities entrapped by the hydrate of alumina. In other words we are undoing the good work we have done. Moreover, the volume of impurities going to the filter is far greater than it should be and the filters are requiring altogether too frequent washing.

Shortly afterwards a very singular manifestation takes place. The filters, which have been delivering a gradually deteriorating effluent finally refuse to deliver any water at all. An examination of the sand after washing shows it to be perfectly clean and there is no apparent reason why the water should not pass through. Nevertheless the filters are nearly impervious. A more thorough examination develops the fact that the pipes in the underdrains of the filters have become completely filled with a fungus growth, usually beggiatoa or sewage fungus. We clean it out and in a few days the same condition occurs again, the water that does come through is unusable.

The above conditions might take place in a filter plant provided we were confined to sulphate of alumina. However, with a knowledge of troubles about to occur we can guard against them by taking the proper precautions. The Imhoff tank which has been recently so successful in the removal of sludge from sewage might be applicable in this case, but there is a consider-

able doubt in the writer's mind whether complete decoloriza-
tion of the water could be effected by filtration after the water
had passed through such an apparatus without a subsequent
chemical treatment.   It is necessary to stop the fermentation of
the precipitated matter.   We can often do this by the addition
of copper sulphate in fairly large proportions, say for instance,
two or three parts to the million.   This in certain cases is
sufficient.   The fermentation stops, sedimentation is good, the
growths in the pipes gradually disappear, the effluent of the filter
becomes clear, sparkling and odorless and everything is satis-
factory.   However, there are many cases where copper sulphate
cannot be used in sufficient quantities, or where it is not useful
at all.   Where the percentage of sewage is very high we find
that there is much undecomposed and unprecipitated organic
matter in the water and to get really satisfactory results it must
be consumed in some manner.   Some powerful oxidizing agent
is required.   In such instances calcium hypochlorite recommends
itself.   This is to be used very judiciously as a very faint excess
indeed would produce the most disastrous results in dyeing,
but when accurately applied it consumes the dissolved organic
matter as thoroughly and as effectually as if it were dried and
burned in a fire.   Moreover, it is a tremendously powerful bac-
teriacide and a bacterial analysis of the treated water shows it
to be almost sterile even before filtration.

At Passaic, N. J., using Passaic River water, which runs
about one million bacteria per cubic centimetre, or equal to
ordinary sewage, it was found that with two parts per million
of calcium hypochlorite and five hours' sedimentation the
bacteria ranged from twenty-seven to one hundred per cubic
centimetre, and that so long as the hypochlorite was used there
was no tendency whatever of the sludge at the bottom of the
basin to ferment.

In most plants the amount of calcium hypochlorite employed
ranges from one to three parts per million.   Where fermenta-
tion is interfering with sedimentation it must be applied as the
water enters the sedimentation basin but if sedimentation is
reasonably good an economy can be effected by applying the
calcium hypochlorite after sedimentation is completed.   By fol-
lowing this procedure much of the oxidizable matter that would
be precipitated by the alum has settled to the bottom and the

principal oxidizing activity of the hypochlorite is directed against the dissolved matter and the bacteria.

Another action of the calcium hypochlorite is to decolorize the dyes that may have resisted action of the aluminum sulphate. This action, however, is not especially important as the strength required to produce this result is usually greater than is safe to use.

Needless to say the treated water must show no trace whatever of free calcium hypochlorite and the only logical way of attaining this result is to keep the quantity of chemical applied at such a point that its energy will be entirely expended upon the organic matter. An accurate chemical feed is of the utmost importance when using the calcium hypochlorite.

With certain waters it is found that although a suitable degree of precipitation is obtained by the use of the aluminum sulphate the precipitate is of a flocculent, buoyant nature and will not settle. In fact it has a tendency to come to the surface of the water. On examination it will be found that the buoyant tendency of the precipitate is due to small bubbles of carbonic acid gas given off in the reaction between the sulphate of alumina and the earthy carbonates. If the water is soft this tendency is corrected by adding either shortly before the application of the aluminum sulphate, or shortly after, a small quantity of calcium hydrate. This calcium hydrate absorbes the free carbonic acid gas with great avidity and the flocculent precipitate falls to the bottom of the settling basin at as rapid a rate as could be desired.

In the above examples we have mentioned the beneficial action that takes place in the tendency of one set of wastes to neutralize another; the treatment with sulphate of alumina to produce precipitation and sedimentation; the additional treatment by antiseptics to prevent further bacterial action and to inhibit the growth of other objectionable vegetable organisms and the oxidization of the excess of organic matter.

There is still another feature to be considered which is of especial importance on small streams to which at times extremely large quantities of defiling matters may be discharged for short periods of time, and that is the advisability of directly avoiding this extreme contamination, or producing such a degree of dilution that the problem involved is a very slight one.

The writer has in mind a small stream on which is located a paper mill. A few hundred feet below this paper mill is a felt mill drawing its supply from the same stream, the flow of which runs as low in dry weather as one and one-half million gallons per day. At certain irregular periods the digesters containing large quantities of free caustic soda together with the saponified grease, resin, pectin and various other substances extracted from the rags, etc. are discharged into the stream. This proportion of impurities at the time of discharge is so great that the alkalinity of the stream is raised from sixty parts per million to twelve hundred parts and the basin below the dam where the water falls over is frequently filled to a depth of six feet with what appears to be soap-suds.

The effect of alkali upon wool is disastrous and the felt mill experienced great trouble with the soda. They even went to the trouble of stationing a man at their head gate some eight or nine hundred feet above their mill with instructions to close it at such times as he saw the digester discharge coming down. As soon as this substance had passed by, usually a period of not more than twenty minutes, the gate was opened again, the head race holding enough water to supply the mill in the interim. This was manifestly a clumsy way of avoiding the trouble. The real solution of the problem was worked out in the following manner: At the lower end of the head race near the mill a settling reservoir holding a half million gallons of water was constructed at such an elevation that the water flowed by gravity into it. The water for the mill was drawn from the opposite side of the reservoir to the point at which it entered. The amount of strongly alkaline water entering this reservoir was so small in proportion to the entire body of water in it that it not only had no deleterious effect but the alkali actually tended to soften the main body of water in the reservoir.

The point I wish to make in this connection is, that only a small amount of the highly alkaline water enters the reservoir, the major portion of it passing the inlet and going on down stream, the quantity entering the reservoir being such a small portion of the whole body of water that even if it had no beneficial effect it would be so greatly diluted that its treatment would be a very small matter.

The quantity of water required in the various industries is

very great in comparison to the requirements of municipalities. For instance, a supply of two million gallons per day would furnish a town of 20,000 inhabitants, a small paper mill of say twenty tons daily output, a very small bleachery, or a small silk dye-works. The largest silk dye-works in this country consumes 23,000,000 gallons of water per day and a contract has just been let for a bleachery in the New England States requiring a filter plant having a capacity of 36,000,000 gallons per day. This is approximately the amount of water used by the city of Philadelphia west of the Schuylkill. These figures seem stupendous to the person who has not studied industrial requirements.

A pound of muslin, or similar cotton fabric requires in the bleaching process about twenty-seven gallons of water. A pound of paper requires about fifty gallons of water, and a pound of silk not less than one thousand gallons of water. Moreover, many of these processes in which water occupies such an important part include very delicate chemical reactions in which strong acids and alkalies play their part.

The dyeing of silk in the skein is an interesting example of the importance of a sufficiency of very good water. The dyer receives a quantity of silk and some sample colors. Say for instance, one hundred pounds of silk are delivered to him to be dyed a pale blue, and white. He receives instructions to return two hundred pounds of silk. The first operation through which the skein is put is to place it in a bath of soapy water and boil it for a period of time. This removes the natural gum or seracine from the fibre, and after drying it is found that the one hundred pounds of silk now weighs but seventy-five.

The next process is to make this seventy-five pounds of silk weigh two hundred pounds. This is effected by hanging the silk in a bath of bichloride of tin. After a certain period of time the dyer estimates the fibre of the silk has absorbed enough tin to weigh the necessary two hundred pounds. This is not a deposit of a metallic salt upon the fibre but is a chemical combination that has taken place between the fibre and the tin. It cannot be washed off nor out, and practically the only process by which the tin could be separated would be by burning the silk. This bichloride of tin is a very corrosive substance and the silk cannot be handled with the naked hand until after it has

been washed to remove the excess.   Washing is effected by hanging the skeins over the revolving rolls of a washing machine against which thousands of needle-like jets of water are directed. After this washing the silk is treated with a dilute solution of sodium phosphate and is again run through the washing machine.   If the silk has not taken up enough tin to reach the desired weight it is again placed in the tin bath and the same process is gone through, sometimes a half dozen treatments being required to gain the requisite weight.

The dyeing of the silk, either white or colored, is usually done in a hot soap bath to which the dye is added, and to give additional body to the bath a part of the seracine extracted from the silk in the early part of the process is put in it.   It is not customary in this country to bleach silk, the white being produced by dyeing it purple and exhausting the color in an acid bath. This is done by dyeing the silk red and blue and the shade of white eventually evolved depends upon the proportions of red and blue used.   This dyeing process is rather mysterious to the uninitiated.   The dyes used are not faint reds and blues but when mingled produce an intense purple which, of course, is deposited on the silk.   The immersing of these purple skeins in the acid bath and the rapid transition from purple to silvery white is a most interesting and attractive process.

After a period of time in the acid bath during which the scroop, the trade name for that property which gives to silk its rustle, is formed, the skeins are again washed and passed through the hydro-extractor after which they are placed in a steam-tight compartment, stretched under a pull of several thousand pounds and live steam turned in on them for a minute or so. They are then taken out, hung over a smooth stick, twisted, yanked and otherwise mauled by a strong determined man for two or three minutes.   This terminates the dyeing process and the dull yellow, linen-like skein, not half as big round as one's wrist has been converted into a silvery fluffy mass of shining fibre at least four times its original bulk, for during the absorption of the weighting materials the silk has increased greatly in volume.

The owner of the silk then receives the two hundred pounds of silk for the one hundred delivered, which seems very much like getting something for nothing until you realize that the dyer

gets anywhere from $1.50 to $3.50 per pound on what he re-
turns for his pay.

It is possible to weigh a pound of raw silk up to sixty ounces,
so that little more than twenty per cent. of the fibre itself is
silk, the rest being weighting substance. Needless to say the
wearing value of such silk is almost nothing.

In the above process large quantities of water are used in the
boiling off of the seracine. Soft water is desirable as it pre-
vents the formation of lime soaps. In the washing, after the bi-
chloride of tin bath the water must be absolutely bright and color-
less and is preferably hard from earthy carbonates. Any trace
of color in this water will be immediately precipitated by the
acid upon the silk and produce a stain. Then again, after be-
ing placed in the sodium phosphate bath if there were any trace
of color or vegetable matter in the water it would be precipitated
upon the silk fibre in such a manner as to act as a resist in the
subsequent dyeing process with the result that streaky skeins
would be produced. This tendency is so strong that even jet
black silk will show streaks in it if the water is not perfect.

Perhaps the most important point of all is the acid bath in
which most skein silk of every color is placed to produce the
scroop. If there is any trace of color in this water to which
a small amount of acetic acid has been added, when the skeins
are placed in it this color will deposit itself upon the silk in the
most incredible manner and a skein dipped a few times in this
water will come out very much off color. This tendency of the
color to deposit itself on the fibre is so strong that when the
water does not appear right to the dyer, without any further in-
structions he takes a batch of silk which is to be dyed a dark
color and runs it first through this acid bath so that all of the
color will be precipitated upon it, after which he can place his
light colors and whites in it with impunity.

Still another dangerous point is the final washing of the
silk after removing it from the acid bath. This wash water
must naturally be very pure as otherwise we would have a de-
posit upon the silk from it.

Until a comparatively recent time nothing but spring or well
water was used for the whites and light colors. There is one
silk dye-works in Paterson, N. J. that has seventy-five 8 inch

artesian wells, none of which are less than three hundred and fifty feet in depth, all of them drilled through the red sandstone.

So much has been said in this article about forms of contamination by industrial wastes and the benefits of filtered water that possibly a brief description of the two general types of filter plants would be interesting.

There are two kinds of filters, pressure and gravity.   Really they are identical in operation, the only difference being in their application.   The pressure filter is the same device as the gravity filter excepting that it is placed in an enclosed steel tank and operates under whatever pressure the service main may carry, delivering its water filtered and still under pressure with a loss of head ranging from two to ten pounds, depending upon the make of filter.

The gravity filter on the other hand relies upon the weight of water on it to drive the water through the bed and the water is discharged at the bottom under no pressure.

Taking the detailed parts of a gravity filter plant for an example, we find that they consist of a chemical feed, a settling basin with the necessary baffles, the filter proper and the machinery for washing the filter.   As the consumption of every industry varies more or less from moment to moment there are fluctuations in the rate of flow of the raw water coming to the settling basin.   The chemical feed must be an apparatus that will regulate whatever chemicals are being applied to meet this fluctuation.   For instance, if the feed is set to apply two grains of sulphate of alumina and one-eighth of a grain of calcium hypochlorite per gallon of water it must do that and exactly that, whether the plant is running at full speed, one-quarter speed or a twenty-five per cent. overload.   It is a small but vital part of the entire plant and might be compared in its way to the governor of a steam-engine.   Of course, chemicals are applied in the form of solutions of a definite strength.

The water after receiving its dose of chemicals flows through the settling tank in a continuous process, in at one end and out at the other.   To stop the tendency of the water to flow directly across the basin from inlet to outlet leaving a large eddy on either side, baffles are placed so as to compel the entire body of water to take a circuitous course through the basin.   Much of

the solid substance in the water has already been coagulated by the action of one set of impurities upon another, and the applied chemicals have produced further precipitation and have, moreover, gathered together the finer particles of suspended matter into comparatively large masses so that all settle with considerable rapidity toward the bottom of the basin, where they remain until such time as it is convenient to remove them. The hypochlorite used is sufficient to prevent fermentation if the water is highly contaminated with sewage. Moreover, the alum applied has exhausted such remaining dyes as have not been precipitated prior to the time it was added.

Finally the water reaches the far end of the settling basin. It is much clearer, has much less color, the odor has practically disappeared and there seems to be a decided improvement in every way. It is far from being fit for use however. It is then conducted to the filters through the necessary pipes, passes down through them and every trace of suspended matter is removed with the result that a water that three hours before was very dark in color, had a strong odor of sewage and contained much suspended matter is as bright, sparkling and clear as the clearest spring water, and, so far as the senses can determine, is its equal in every way.

The three essential parts of a filter itself are the case, the filter bed proper and the strainer system. The case is of either steel, wood or concrete. The filter bed itself is of carefully selected sand and the strainer system, which consists of a series of pipes leading to all parts of the bed terminating at their outer ends in strainers or sand valves, devices which have slots or perforations of too small a size to permit the sand to pass through, but sufficient in number to allow a definite quantity of water to leave the sand bed. This strainer system is placed on the floor of the filter, and its object is not only to collect the filtered water from the bottom of the filter but also to distribute the wash water uniformly underneath the bed during the washing process.

Considerable quantities of sulphate of alumina and some hypochlorite of lime have been used. As any trace of either of these substances in the filtered water would utterly condemn it for almost every industrial purpose they must be removed or con-

verted into innocuous substances. This is effected in the fol-
lowing manner: Referring first to the sulphate of alumina, a
previous analysis of the water has been made which shows the
amount of its alkalinity. For every ten parts per million of
alkalinity that the water contains one grain of sulphate of
alumina per gallon can be used with safety, because this quantity
of alkali will combine with the alum to convert it into an in-
soluble substance, hydrate of alumina, which is readily removed
by the filters, and sulphate of lime. In other words, the car-
bonate of lime existing in the water renders the alum insoluble
and converts it into a form in which the filter can hold it. Oc-
casionally we find a water, particularly in the New England
States, so soft that it does not possess sufficient alkalinity to per-
mit the use of alum in sufficient quantities to produce the de-
sired result. In such an event an artificial alkalinity is produced
by the addition of a small amount of carbonate of soda or by
the introduction of corresponding quantities of quick-lime.

Calcium hypochlorite, chloride of lime or bleaching powder,
as it is variously known, on being mingled with the organic mat-
ter is decomposed into calcium chloride, and ozone is liberated in
sufficient quantities to produce the necessary oxidization. Cal-
cium chloride, being an inert salt and existing in such minute
quantities has no significance from any industrial stand-point
whatever. We thus see elimination of the applied chemicals or
their metamorphosis into harmless and insignificant substances.

In addition to economy in the use of chemicals the other costs
of operation such as attendance, power, etc. must be reduced
to a minimum. One hour per day for each million gallons of
water treated is sufficient to cover the attendance of a well de-
signed industrial plant. The sedimentation basins are so ar-
ranged that the sludge drains into a channel passing down the
middle connecting with a blow-off valve. Opening this valve
at intervals of one to six months and permitting the entire
chamber to drain takes care of most of the sludge.

The filters must be so designed that they can be washed very
rapidly and very thoroughly. This is done by simply revers-
ing the current in the case of the pressure filter and forcing the
water up through it at a high rate of speed. This causes the

sand grains to dance up and down rapidly, each scouring the other so that after a few minutes the entire sand bed is cleansed.

In gravity plants an economy in washing can be effected by inducing additional agitation of the sand either by means of a revolving rake or by forcing compressed air under the entire filter bed. Either of these processes produce the same result, that is, very rapid motion of the sand grains and a consequent rapid loosening of the retained impurities.

All types of filters are connected directly with the drain so that wash water can flow to it. Moreover, the first water that comes from the filter after washing is of poor quality and it is customary to filter into the drain for a minute or two or until the filter bed gets thoroughly packed. Depending upon its design, an ordinary filter will wash in from five minutes to an hour's time, and will consume from two to fifty per cent. of the water filtered for washing. The general type of filter used for industrial purposes, however, is designed to be washed very quickly.

From the above it will be seen that the chemical treatment in many industrial problems is as essential as the apparatus itself. Given a properly designed plant employing the proper chemicals, there is no reason why the most polluted American rivers cannot be made satisfactory for all industrial purposes.

The Effect of Mercury Vapor. WERNER VON BOLTON. (*Zeit. Elektrochem.*, xvi, 667.)—A test-tube containing barium amalgam, closed with a vulcanized rubber stopper, was maintained at room temperature for three weeks. The part of the stopper exposed to the amalgam became carbonized, and carbon and microscopic diamonds were found. This carbonization proceeds very rapidly at 100° C. Sulphur hastens the reaction; selenium and tellurium retard it. Vulcanized rubber emits a hydrocarbon gas, which mercury vapor decomposes, as it also does illuminating gas. This decomposition is not preceptible with dried mercury vapor, a definite quantity of moisture seems essential. Mercury vapor also decomposes chloroform, tetrachloride of carbon, carbon disulphide, carbon dioxide and hydrogen sulphide. No reduction to carbon was noticeable when unvulcanized rubber stoppers were used. Probably graphite and diamond were formed in nature by the action of metal vapors, such as iron or magnesium, or carbon dioxide.

THE MEAN DEPTH AT WHICH ROENTGEN RAYS ORIGINATE WITHIN A SILVER TARGET.

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THE modern theory of Roentgen rays states that these rays consist of waves in the ether caused by accelerations received by negatively charged corpuscles during the time in which the cathode rays penetrate the target (or anti-cathode) of the X-ray bulb.

In the *Physical Review,* vol. xxx No. 1, Jan., 1910, Dr. Wm. R. Ham has given a method by which he was able to determine for various potentials the mean depth beneath the surface of a lead target at which the rays originate. In the same

FIG. 1.
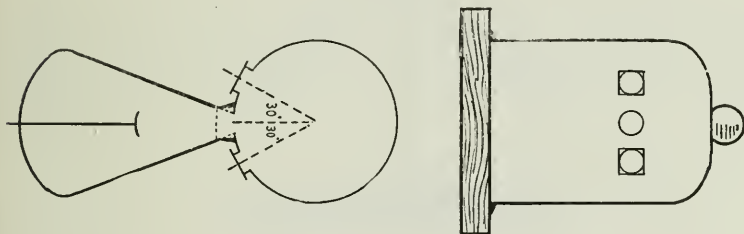
article he shows that the depth at which the rays originate depends on the depth " at which on the average, as many of the cathode particles which have entered the target are suffering accelerations in one direction as in any other." This depth is called the *depth of complete scattering.*

The present research was an effort to determine (*a*) the mean depth at which, for a given potential, Roentgen rays originate in a silver target, and (*b*) to determine the depth of complete scattering for silver at a given potential. Due to a break in the apparatus the completion of the second part of the experiment has been somewhat delayed. The apparatus used was practically the same as was

used by Dr. Ham (see Fig. 1). The X-ray bulb was in the form of a bell-jar of 7 cm. radius and of 16 cm. height. The flange was accurately ground to a plane surface and fitted to a thick plane glass plate. Three holes each 2 cm. in diameter were drilled into the side of the bell-jar at a height of 10 cm. above the flange in such a way that the angular distance along the cylindrical surface of the bell-jar from the centre of one hole to the centre of the next was 30 degrees. Into the central hole was cemented a funnel-shaped tube which held the cathode. The air-pump was attached to this tube. Into the two other holes were ground short glass cylinders. Each of these carried a small glass window. These two windows were cut from the same

FIG. 2.
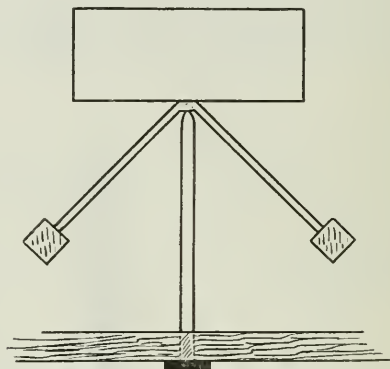
sheet of glass and were of the same thickness. The joints between the windows and their cylinders and between the cylinders and the bell-jar were made air-tight by means of Kotinsky cement. All other joints were made air-tight by means of mercury seals. These joints were so perfect as to hold a good vacuum for several months.

The target (see Fig. 2) was pivoted on an upright post at the centre of the bell-jar so that it could be placed at any desired angle to the cathode stream. Iron balancing weights made it possible to adjust the target magnetically from the outside of the tube. The positions chosen were such that the normal to the target passed through one or the other of the windows

mentioned above, *i.e.* the cathode stream made an angle of 30 degrees with the normal to the target.   The tube was excited by means of a 12 plate Holtz machine electrically driven.   Fig.

Fig. 3.
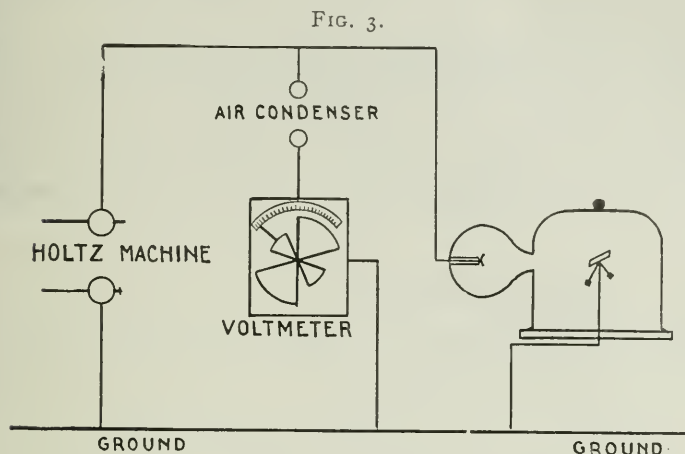
3 shows the scheme of electrical connections.   A gold-leaf electroscope (Fig. 4) provided with a micrometer-microscope was placed opposite each window and the amounts of the discharges

Fig. 4.

GROUND
G – GLASS WINDOW
P – PAPER WINDOW
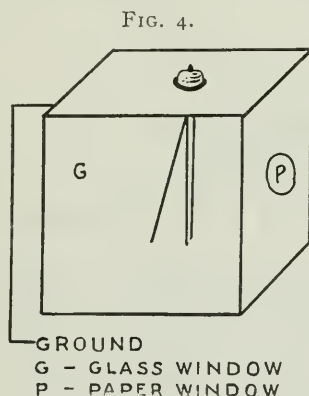
were taken as proportional to the intensities of the X-rays.   Each electroscope was cubical in shape and was made of sheet brass. Two large glass windows and one small paper window were provided in each as shown in the figure.   An 8 c. p. incandescent

bulb was placed near one of the windows to illuminate the gold
leaf.   The microscope was placed so as to point towards the
opposite window and its scale was thus illuminated directly by
the lamp above mentioned.   The X-rays were admitted through
the paper window.   All rays except those from the uniform
windows were screened off by means of thick lead sheets.

The electroscopes were charged to a P. D. of 340 volts by
means of a battery of dry cells the positive end of which was
grounded.   The relative positions of cathode target and electro-
scopes are shown in Figs. 5 and 6.   For convenience of reference

FIG. 5.
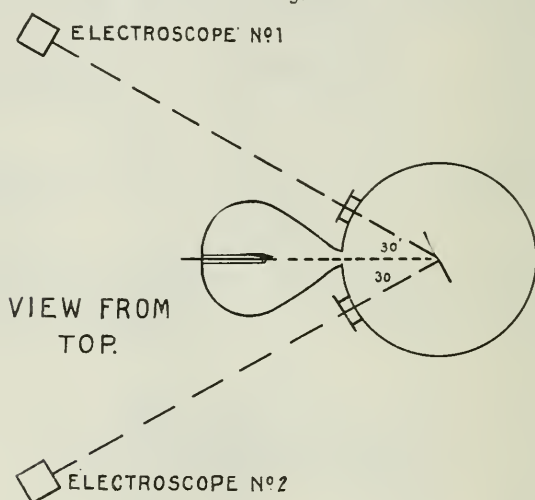
the parts are lettered as in the above-mentioned article by Dr.
Ham.

Let *o* be the source of some ether pulse and let *o* be so
situated as to be at the mean depth at which X-rays originate.

Let $l_1 - l_2 = x =$ the excess of silver which the pulse
has to traverse in passing to electroscope No. 1 over that which
it traverses in passing to No. 2.

Let *h* be the perpendicular distance from *o* to the surface of
the target.

Let *d* be the distance from *o* to the point at which the cathode
ray enters the target.

Let θ_0 be the angle which the lines from the electroscopes to the target make with the cathode-ray stream.

Let θ be the angle which the normal to the target makes with the cathode ray stream.

Then
$$x = h\left(\frac{1}{\cos(\theta_0+\theta)} - \frac{1}{\cos(\theta_0-\theta)}\right).$$

But
$$h = d\,\cos\theta.$$

Therefore
$$x = d\,\cos\theta\left(\frac{1}{\cos(\theta_0+\theta)} - \frac{1}{\cos(\theta_0-\theta)}\right),$$

or
$$x = dF(\theta, \theta_0).$$

It is evident from the figure that the rays going to electroscope No. 1 must travel a greater distance through the target

Fig. 6.

KATHODE STREAM

TO NO. 1

NORMAL TO TARGET

TO NO. 2

oa = l
oe = l
ob = d
oc = h

ENLARGED VIEW
OF TARGET
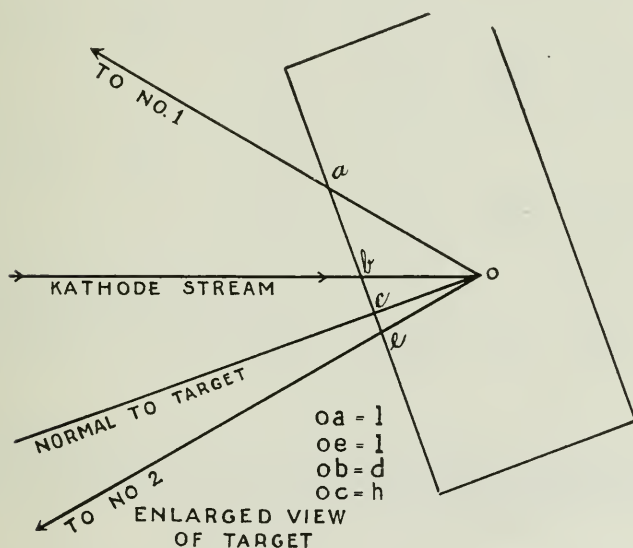
than must the rays going to electroscope No. 2. They will therefore suffer more absorption. If I_0 represents the intensity of the ray going towards No. 2 at the moment of emergence from

the target, and if I represents the corresponding intensity of the ray going towards No. 1, then

$$I = I_0 \varepsilon^{-\lambda x}$$

where x is defined as above and λ is the coefficient of absorption. λ is found experimentally for each potential used. I and

TABLE I.

To Find the Coefficient of Absorption of Silver for X-rays Generated from a Silver Target at a Potential of 17,000 Volts.

Time	Discharge		Discharge cor. for natural leak		No. 1 cor. for calibration	Per cent. remaining after absorption
Min.	No. 1	No. 2	No. 1	No. 2		
21	26.7	89.8	25.8	88.8		
24	27.9	90.2	26.8	89.0		
28	29.8	93.0	28.7	91.7		
			81.3	269.5	86.7	32.1
24	26.9	90.6	25.8	89.4		
24	29.0	94.6	27.9	93.4		
24	27.3	88.1	26.2	86.9		
			79.9	269.7	85.3—	31.6
22	29.1	92.0	28.1	90.9		
22	26.9	88.0	25.9	86.9		
25	29.6	92.2	28.5	91.0		
			82.5	268.8	88.0	32.7
21	26.4	90.0	25.3	89.0		
22	28.5	88.8	27.5	87.7		
22	28.1	90.1	27.1	89.0		
			79.9	265.7	85.3·—	32.1

Average per cent. remaining, 32.1.
Greatest deviation from average, 1.9 per cent.
Thickness of absorption sheet $= x = 0.00263$ cm.

$$I = I_0 \, \varepsilon^{-\lambda x}$$
$$\lambda = 432.1$$

I_0 are directly proportional to the readings of the electroscopes. Therefore x is known. The value of d may then be calculated

from the equation $x = d\ F\ (\theta_0, \theta)$. For the actual angles used $F\ (\theta_0, \theta) = 0.866$ so that

$$d = \frac{x}{0.866}.$$

The electroscope discharges were corrected for the natural rate of leak. By simultaneously determining the amounts of the discharges under exactly similar conditions the ratio between

TABLE II.

To Find the Coefficient of Absorption of Silver for X-rays Generated from a Silver Target at a Potential of 10,000 Volts.

Time	Discharge		Discharge cor. for natural leak		No. 1 cor. for calibration	Per cent. remaining after absorption
Min.	No. 1	No. 2	No. 1	No. 2		
71	21.0	87.8	17.9	84.4		
72	22.0	87.8	18.8 +	84.3		
74	22.0	88.1	18.7 +	84.8		
			55.4 +	253.5	59.1	23.3
83	20.6	84.4	16.9	81.4		
80	20.3	85.1	16.8	81.3		
71	19.9	82.9	16.8	79.5		
			50.5	242.2	53.9	22.3 −

Average per cent. remaining, 22.8.
Greatest deviation from average, 2.2 per cent.
Thickness of absorption sheet $= x = 0.00263$ cm.

$$I = I_0\ \varepsilon^{-\lambda x}$$
$$\lambda = 562.1$$

Summary of results on coefficient of absorption.
At 17,000 volts, $\lambda = 432.1$ ⎱ for absorption of rays from a silver target by a
At 10,000 volts, $\lambda = 562.1$ ⎰ sheet of silver.

their readings was determined. Then by means of this ratio the corrected reading of No. 1 was expressed in terms of the reading that would have been shown by No. 2 under similar conditions.

Average rate of natural leak of electroscopes:

Electroscope No. 1................0.044 divisions per minute.
Electroscope No. 2................0.048 divisions per minute.

Calibration of electroscopes under similar conditions:

Rays generated by lead target.
1.065 (X-rays generated at 17,000 volts)
1.065
1.068 (X-rays generated at 10,000 volts)
———

1.066 mean.

Rays generated by silver target.
1.073 (X-rays generated at 17,000 volts)
1.068
1.058 (X-rays genertaed at 10,000 volts)
1.065
———

1.066 mean.

$$\text{Weighted mean} = \frac{\text{No. 2}}{\text{No. 1}} = 1.067.$$

FINAL RESULTS.

At 17,000 volts, x=0.000080 cm.
At 17,000 volts, d=0.000092 cm.
At 10,000 volts, x=0.000047 cm.
At 10,000 volts, d=0.000054 cm.

$$\frac{10,000}{17,000} = 0.59-. \tag{1}$$

$$\frac{0.000054}{0.000092} = 0.59-. \tag{2}$$

From (1) and (2) it is seen that the mean depth at which X-rays originate within a silver target is directly proportional to the potential employed in generating the rays.

In conclusion I desire to thank Dr. Wm. R. Ham for his continual assistance and his helpful suggestions during the course of the experiment. Thanks are also due to Mr. F. C. Miller for valuable aid rendered during the progress of the work.

TABLE III.

To Find the Mean Depth at which X-rays Originate in a Silver Tar- get (a) when the Rays are Produced at a Potential of 17,000 Volts, (b) when the Rays are Produced at a Potential of 10,000 Volts.

P. D. = 17,000 VOLTS.

Time	$L*$ $R\dagger$	Discharge		Discharge cor. for natural leak		Calibration	Final No. 1	$\dfrac{I}{I_0} = \varepsilon^{-\lambda x}$
Min.		No. 1	No. 2	No. 1	No. 2			
26	L	81.0	89.7	79.9	88.5	1.073	85.8	0.969
25	R	79.6	82.7	78.5	81.5		84.2	0.967
27	R	77.7	80.0	76.5	78.7		81.3	0.963
23	L	77.7	86.0	76.7	84.9	1.068	81.5	0.965 −
							Mean,	0.966

P. D. = 10,000 VOLTS.

61	L	82.8	91.0	80.1	88.1	1.065	85.3	0.968
67	R	84.9	88.4	82.0	85.2		87.3	0.976
72	R	84.1	87.1	80.9	83.6	1.058‡	86.2	0.970
76	L	83.2	90.1	79.9	86.5		85.1	0.984
							Mean,	0.974

* Readings marked L were taken with the normal to the target making an angle of 30 degrees to the left of the kathode stream.

† Readings marked R were taken with the normal to the target making an angle of 30 degrees to the right of the kathode stream.

‡ The value 1.066 was used in calculation as there was noticed to be some fluctuation in the voltage while the last reading was being taken.

The calibration $\left(= \dfrac{reading\ of\ No.\ 2}{reading\ of\ No.\ 1} \right)$ was found *for each pair* of read-

ings as follows, $\dfrac{1}{2} \left(\dfrac{reading\ of\ No.\ 2\ L}{reading\ of\ No.\ 1\ L} + \dfrac{reading\ of\ No.\ 2\ R}{reading\ of\ No.\ 1\ R} \right)$.

Formation of Nitric Oxide in High Tension Arcs. F. HABER, A KOENIG, and E. PLATON. (*Z. Elektrochem.*, xvi, 789.)—With a continuous arc a maximum percentage of nitric oxide (8.16) was obtained when the pressure was about 150 mm. At higher pressures the arc did not fill the quartz tube, and the effect of water cooling was diminished. With alternating current the power efficiency was determined. The power factor was ascertained with a current of not too high frequency by a Dolezalek electrometer. The best yield with 0.7 kilowat was 57 Gm. of nitric acid per kilowatt hour, the concentration nitric oxide was 3.4 per cent.

The Future of Aerial Navigation. (*Amer. Mach.*, xxxiii, 745.)—The repeated accidents with flying machines, both aeroplanes and dirigibles, culminating in the disaster to the Zeppelin VI, lead to the conclusion that in spite of wonderful technical progress, little has been done toward surmounting the inherent dangers. The dirigible would seem essentially the safer type. Nevertheless five Zeppelin airships have been destroyed, three by a gale of wind and one by an explosion of the motor. The achievements of the Wright brothers are epoch-making in their importance, but from the commercial point of view, even assuming they can be rendered fairly stable by the use of gyroscopes or other devices, the uneconomic use of power seems a serious drawback to their development. The aeroplane is probably capable of greater speed than any form of land transportation, which puts it in a class by itself for certain purposes, such as army scouting and possibly offensive attack; but much remains to be done before it can be considered a commercial vehicle in any sense.

Colloidal Silver as an Intensifying and Toning Agent in Photography. A. NEUGSCHWENDER. (*Z. Chem. Ind. Kolloide*, vii, 214).—When silver ferrocyanide is treated with stannous chloride solution and then with ammonia solution, a dark brown solution is obtained, from which a precipitate of colloidal silver separates after some time. This reaction can be utilized for intensifying or toning of photographic images, the silver being first converted into ferrocyanide by treatment with an alkaline ferrocyanide. The intensification produced is greater than that obtained with mercury and ammonia, but less than that from uranium. Dark brown tones are obtained on bromide paper, which can be converted into bright brown and red brown tones by subsequent treatment with dilute hydrochloric acid or ammonium chloride solution. When stannous nitrate and sodium carbonate are used instead of stannous chloride and ammonia, the intensification is stronger, but still less than that produced by uranium. Other amorphous silver compounds are converted into colloidal silver by stannous salts and alkalies, but the ferrocyanide process appears the only one which can be used in photography.

THE NEW IRONCLAD-EXIDE BATTERY FOR ELECTRIC VEHICLES.

BY

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INTRODUCTION.—The very simplicity of the electric vehicle at first tended to retard its development, no fundamentally new type of construction being deemed necessary. A battery and a motor on an ordinary vehicle made a horseless carriage.

An appreciation of what can be accomplished with properly designed electrics has now been gained. This has been largely the result of a still growing spirit of co-operation between the vehicle maker, the battery maker, the central station, and the user, which has led each to study the general situation and to try and adapt his special part to the best interest of the whole. The result is the rapid increase in the use of electric vehicles— both pleasure and commercial.

BRIEF HISTORY OF LEAD STORAGE BATTERY.—The battery generally manufactured for vehicle propulsion is of the lead sulphuric acid type. This type was discovered by a Frenchman, Gaston Planté, in 1860. It includes both the Planté and pasted types. To the Planté type belong all those lead batteries whose active material is obtained by means of chemical or electrochemical corrosion of the lead support plates, and whose electrolyte is a solution of sulphuric acid in water. Various modifications of the Planté type have been tried for vehicles with moderate success.

The pasted type, developed almost simultaneously in 1880 by Camille Faure in France, and Charles Brush in this country, is now generally used for electric vehicles. It includes all those batteries in which the active material consists of a paste made of lead oxide applied to a grid.

THE EXIDE BATTERY.—In the development of the lead sulphuric acid battery for vehicle service the problem has always been to secure high capacity per unit of weight consistent with

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durability. Although previously made spasmodically the earliest application of the battery to the electric vehicle on a large scale was made in the late nineties, with the chloride accumulator, a modified form of the Planté type. Although at the time this was considered successful, and long experience has proved its durability, yet greater capacity per unit of weight soon became necessary.

To meet this need the " Exide " battery was introduced in 1900, and since that time has been a most widely used battery for automobile propulsion. Although improved from time to time it has remained unaltered in its essential principles. As this battery is so widely known, time will not be taken to further describe the details of its construction, except such features and characteristics as bear upon the further development of storage batteries for vehicle use.

Among these is the form of grid made of a stiff lead alloy to give strength and resist corrosion. Its principal feature is the cage structure to hold the active material firmly in place in the form of a narrow vertical ribbon between vertical conducting ribs. This feature is used in all sizes and thicknesses of Exide plates, both positive and negative. The ribs and cross bars of the negative grid are lighter than those of the positive.

The positive and negative plates are made by pasting the grids with lead oxides and treating them electrochemically to produce a lead peroxide in the positive plate and spongy lead in the negative plate.

The Exide vehicle battery plates are manufactured in two standard sizes and several thicknesses, one of these being the Hycap Exide. The rating for plates known as Exide is based on a four-hour rate of discharge which is roughly one ampere per pound of complete cell. The capacity of the Exide plate rapidly rises in service and then gradually falls off. However, the initial rating is conservative, so that if a battery be given its proper initial charge it will give the rated four-hour discharge at the start. This will gradually increase in use to four and a half and even to five hours at the same rate of current. The increase to a maximum is more rapid than the dropping off from the maximum. This rapid rise in capacity at the beginning of service is due to the increasing porosity of the positive active material. This results in better diffusion of the electrolyte, which

brings more of the lead peroxide into action on each cycle of charge and discharge. However, this rise in capacity is at the expense of active material. For, as more material is brought into action, the active mass softens and then when the battery is charged some of the material is dislodged and settles to the bottom of the cell in the form of sediment. Incidentally this explains why the life is shortened by too much charging. The capacity will increase as long as the rate of increase in the porosity is greater than the rate at which the active material is lost, but, finally, the loss of material will increase faster than the gain in porosity. When this condition is reached the cell will begin to lose capacity.

POSSIBILITY OF FURTHER DEVELOPMENTS OF THE LEAD STORAGE BATTERY.—From the foregoing discussion of the life of the Exide positive plate, it is evident that if the positive active material could be prevented from being detached from the supporting grid and still be retained in a healthy and operative condition, the plate would have a very much longer life.

The makers of the Exide battery have been improving the positive plate from time to time, and, while bending every effort to study and take advantage of the development of the art both in this country and abroad, they were attracted by the claims of a Frenchman who first demonstrated that if positive material could be kept in position it would remain active. He accomplished this by utilizing a pencil of lead peroxide surrounding a conducting core and exclosed in a porous tube of such elastic quality that as the active material expanded and contracted, due to changes in its molecular structure, the circular tube compensated for these variations. Thus the positive material was protected and held in position. At the same time this form comprising, as it does, a central conducting core embedded in a cylindrical pencil of peroxide of lead, provides excellent conductivity and increased accessibility for the electrolyte, thereby rendering it possible to obtain a relatively high output from a relatively small quantity of active material.

The makers of the Exide battery, after a careful investigation of this new battery, secured the American patent rights. For several years they have been actively but quietly carrying on a process of development in order to adapt the original form, which was somewhat crude and frail, to the demands of com-

mercial use. As a result, they have developed a battery with a positive plate which not only possesses all the desirable characteristics of the Exide positive, but which has even a greater capacity per unit weight and which is so constructed that the loss of its active material is reduced to a minimum. On account of its remarkable durability, this battery is called the Ironclad-Exide.

THE IRONCLAD-EXIDE BATTERY.—The positive plate of the new battery (Fig. 1) consists of an alloy framework, comprising top and bottom bars integrally connected by conducting cores of the same material. Surrounding these cores are the uniform pencils of active material protected by horizontally laminated rubber tubes. Each tube is formed with two narrow vertical ribs diametrically opposite each other which take the place of the
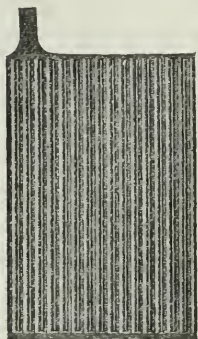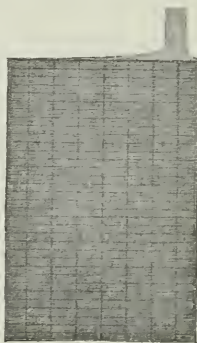
Fig. 1.   FIG. 2.   FIG. 3.
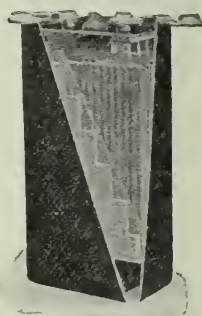
spacing ribs on the ordinary wood separator, and, at the same time, give added strength and durability to the tube.

The negative plate (Fig. 2) is of the same general construction as the regular Exide negative, but it has been made somewhat thicker in order to withstand the longer life of the Ironclad positive. The outside negative plates are thinner than the inside negatives. Both the positive and negatives of the Ironclad-Exide are made in the two standard sizes MV and PV.

The plate lugs have the same dimensions as those of the Exide plates of regular thickness, and the plate centre spacing is the same.

The wood separator used with this battery is a thin sheet of chemically treated wood, flat on both sides.

The pillar straps for connecting the plates are similar to the standard Exide pillar straps. An improvement in detail is that the top of the pillar is bevelled, which facilitates burning the connecting straps.

A feature of the Ironclad-Exide battery is the flexible pillar strap connector. It consists of alloy terminals cast around lead-plated copper strips which give great conductivity and flexibility, and are replaced even more easily than the stiff pillar strap connectors used with Exide batteries. These flexible connectors are standard with the Ironclad-Exide.

Fig. 3 shows an assembled cell cut away to show construction. The jar is the same as that used for the Exide cell. The positive and negative plates are separated by the thin flat wood separators. No rubber separators are required since the positive plate provides its own separator in one of its essential features—the rubber tubes with the ribs thereon. Otherwise the method of assembling is exactly the same as that developed through long experience and employed for Exide batteries.

CHARACTERISTICS OF THE IRONCLAD-EXIDE.—The Ironclad-Exide elements are interchangeable with Exide elements. Users of Exide batteries who desire to take advantage of the increased capacity and life of the Ironclad-Exide can therefore substitute Ironclad-Exide elements for Exide elements without discarding any of the other parts of their batteries. Obviously, these elements may be put into any existing battery, having jars of appropriate size. To give a concrete example, a twenty-four-cell nine MV Exide battery, weighing approximately 720 pounds complete, including trays, and rated at 28 amperes for four hours, will receive nine MV Ironclad elements. It then will weigh approximately 740 pounds, with an initial rating of 28 amperes for four and a half hours, or 30 $^2/_3$ amperes for four hours.

The rating is conservative, yet, when compared with the Exide positive, which is rated at 7 amperes for four hours, there is an increase of 12.5 per cent. in initial rating.

This battery, like the Exide, has the well-established advantages of the best lead storage batteries: high discharge voltage and high efficiency.

The same conservative rating is applied to the Ironclad-Exide as is applied to the Exide battery. Using the four-hour rating of the MV Exide, which has been taken as a standard in our

previous discussions, at the same rate of discharge current per positive plate (that is, 7 amperes) the Ironclad-Exide battery, weighing but little more, will start in at four and a half hours, which is an initial increase of 12.5 per cent. in ampere-hours output. It will reach a capacity of from four and three-quarters to five hours within about 25 discharges, and from five and a half to six hours within about 200 discharges. It will then retain a capacity above its rating for practically its entire life, in some cases reaching over 1000 cycles before dropping below its four and a half hour rating. The weight efficiency of the Ironclad-Exide will vary somewhat with the size of battery, mounting, and number of cells. A twenty-four-cell nine-MV Ironclad-Exide battery, arranged in three trays to the best advantage would weigh approximately 740 pounds. The initial capacity at the four and a half hour rate, would be about 8 watt hours per pound of complete battery, increasing to a probable capacity of over 11 watt hours per pound of complete battery.

OPERATION OF THE "IRONCLAD-EXIDE."—For the present, the Ironclad-Exide batteries are being assembled and charged only by the manufacturer. The instructions for their operation are even more simple than those for the Exide batteries.

Besides publishing detailed instruction books, the maker of the Ironclad-Exide battery has established many Exide depots and has provided inspectors to co-operate with the vehicle manufacturers, salesmen, and central stations in a general campaign of education. Users of pleasure vehicles who charge their own batteries are urged to take their cars periodically to an Exide depot for inspection or to have one of the travelling inspectors call on them when in their neighborhood or to consult the central station from which they purchase current in case there are any matters connected with operation not clear to them. Difficulties sometimes arise from the false ideas of fixed voltage and fixed specific gravity. Also a disorder may be attributed to the battery when some mechanical part of the vehicle is at fault.

Give the mechanical parts of the electric car even a fraction of the care demanded by those of the gasoline car, instead of the almost total neglect often accorded them.

To determine whether trouble is in the mechanical parts or in the battery, the ampere-hour meter is sometimes useful, since it measures the output of a battery and the amount of current put

into it. For instance, a car travelling a given route taking more ampere-hours than when previously travelling over the same route, under similar conditions, must have something wrong with its mechanical parts. Thus the ampere-hour meter is a valuable check, though the mistake of relying entirely upon its detection of trouble must not be made.

The keynote to successful operation is system in the observance of the following salient points, which are here briefly touched upon :

1. Keep the electrolyte above the tops of the plates.

2. Add pure water in replacing evaporation, never acid.

3. When a battery is discharged, and especially when a vehicle is stalled, resulting in over discharge, charge as soon as possible.

4. Do not overcharge unnecessarily, although by overcharging the Ironclad-Exide battery will not suffer damage to the same extent as other lead batteries.

Formerly, great stress has been laid upon frequent and systematic cleaning; but the " Ironclad-Exide " will rarely, if ever, require cleaning, since its active material is so firmly held in place, and consequently the rate of sediment deposit is extremely slow. " To determine whether it will be necessary to remove the sediment it is advisable after the battery has been charged 250 times, to cut out for inspection one cell from the centre of the battery. Then from the height of the sediment, estimate its rate of deposit, allowing a sufficient margin in making the estimate to ensure cleaning *before the sediment can possibly reach the plates and* shorten their life by short-circuiting them."

ADVANTAGES OF THE " IRONCLAD-EXIDE."—The " Ironclad-Exide " battery has the inherent advantages peculiar to the lead sulphuric acid type. Among them are :

1. The use of dilute sulphuric acid as an electrolyte.

2. High individual cell voltage.

3. Low internal resistance.

4. High watt-hour efficiency.

5. Relatively small variation between the average voltage of charge and discharge.

6. Ability to discharge at very high energy rates with quick recovery.

7. Low temperature coefficient for temperature correction;

that is, it is effected, but relatively little by temperature changes.

8. Increased capacity at diminished rates.

In addition, because of its particular construction, the " Iron-clad-Exide " battery has the following advantages over the best of other types of lead vehicle batteries, the " Exide " being taken as standard :

1. It gives from two to three times the life.

2. It rarely, if ever, requires cleaning.

3. It will give greater mileage per charge, which considering its longer life and greater percentage rise in ampere hours' capacity per discharge, will mean in a given vehicle upwards of three times the total mileage obtained with the corresponding size of " Exide " battery.

4. These advantages lead, in any given vehicle, under the same conditions of operation, to a substantial reduction in the cost of battery maintenance.

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Pinch-effect Steel Furnace. A. L. Queneau. (*Amer. Electrochem. Soc.*, xvii, 131.)—The pinch-effect is turned to useful account. The fused metal fills the bath of the furnace and two legs extending downward from it, slightly inclined outward. Electrodes are inserted at the bottom of these legs, and a large electrode is suspended above the bath. The metal in the legs is subjected to the hydrostatic pressure of the fused steel above it, and the current is so proportioned that a series of pulsations is set up leading to disruption and re-establishment of the continuity of the molten metal. The experimental furnace takes charges of 225 kg. C. A. Hansen considered any encouragement of the pinch-effect dangerous and thought the lining of the legs of magnesia and pitch would not last, as it became cheesy at steel-bath temperatures. Alundum too, was unsuitable for a lining.

A Good Waterproof Glue. (*Amer. Mach.*, xxxiii, 742.)— This is made as follows :

India rubber	1 part
Mineral naphtha or coal tar	12 parts

heat gently and mix and add

Powdered shellac	20 parts

Pour on a slab to cool ; when used heat to 250° F.

SOIL ORGANIC MATTER AS MATERIAL FOR BIO-CHEMICAL INVESTIGATION.*

BY

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EVERY soil investigator, whether chemist, or bacteriologist, or physicist, studying some special problem, or the agronomist, dealing with the general relation of soils to crops, sooner or later encounters difficulties that have their origin in the lack of knowledge of the chemical composition of the organic matter of the soil.

Some organic matter is essential to make a soil of what would otherwise be pulverized and more or less hydrolyzed rock, and while there are some soils capable of growing crops that contain very small quantities of organic matter, on the whole the quantity of this material in average soils is considerable. Analyses have shown that the average organic content of the soils of the United States is 2.06 per cent. and of subsoils 0.83 per cent.

It is known that the organic matter of soils has its origin in the remains of plants and animals, the former probably predominating greatly, and with the knowledge available regarding the great number of organic compounds present in the tissues of the living plants and animals, it might very well be assumed that soil organic matter would also be made up of many compounds. While, however, there has been no disposition to question the diversity of the organic material from which soil organic matter is formed, there has been an assumption on the part of many that in some mysterious way this conglomerate of plant and animal compounds becomes transformed in the soil into a

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single group of closely related compounds, humic acid, etc., and that no matter how varied may be the organic remains or diverse the conditions of decay, soils vary in organic matter chiefly in quantity.

In contrast to this is another view somewhat common in agricultural literature, that the organic matter of soils is of a very complex nature regarding which very little is known. Little fault can be found with this statement in itself, but it is often made in such a way as to convey the impression that not only do we know little regarding it, but it is almost hopeless to attempt any investigation of it. There is, moreover, seldom coupled with this confession of ignorance any appreciation of the importance of a thorough knowledge of the chemical composition of this important soil constituent.

In considering the importance of a more thorough knowledge of the organic matter of soils, it should be borne in mind that it is material that is for the most part the result of change and that much, perhaps all of it, is susceptible of still further change; that is, it is in a transition stage. The changes which it has undergone and which it may still undergo are determined by a number of factors, chief of which are moisture, aeration, character of microörganisms and the mutual relation of the organic compounds and the mineral constituents. These factors are many of them influenced or controlled by the cultural methods used in practical agriculture including fertilizing, drainage, irrigation, inoculation, etc. Since, then, the common agricultural methods used by farmers are also operations that influence the changes which soil organic matter undergoes, it is plain that the treatment to which this material is subjected under these methods is in part chemical treatment. There can be intelligent chemical treatment of any material only when the chemical nature of the material is known. It is not necessary that the practical agriculturist should know the chemical names or formulas of the organic compounds in the soil, but to the scientific investigator to whom the farmer looks for the " why " of agricultural operations such knowledge is necessary because it carries with it a knowledge of their properties.

The importance of a knowledge of the chemical character of the organic matter of the soil may be considered under four

heads : its effect on crops, its effect on the bacteria and fungi of the soil, its influence on the physical properties of the soil, and its relation chemically to the mineral ingredients of the soil.

It is a well established fact that some chemical compounds which occur in plants and may get into the soil are harmful to growing plants when presented in water solution to the roots. It has also been shown that some organic compounds that occur in soils and have been isolated from them are also harmful to growing plants under these conditions. On the other hand, plants may take up other organic compounds when presented to their roots in water solution without injury to the plant or in the case of some nitrogenous bodies with benefit. Now while the organic matter of soils is for the most part little soluble in water, a water extract of soils always contains some organic matter. In consequence organic compounds have always to be considered as a portion of the material in the nutrient solution supplied to crops growing in the soil.

The chief function of bacteria and fungi is to act on the higher organic compounds from living organisms and convert them into simpler compounds. In other words, these higher compounds are the food of the microörganisms. The simpler compounds resulting from the activity of the fungi and bacteria, commonly spoken of as the products of decay or fermentation, are in part at least still organic substances and help to make up this portion of the soil. No fact regarding bacteria is better established than that they are influenced not only in habit of growth, but also in the character of the compounds produced, by the chemical composition of the medium in which they are grown and are generally intolerant of the presence of an excess of their own by-products. The soil organic matter impregnated with the soil solution is then the culture medium on which soil microörganisms have to grow and contains also the products of their growth. Bacteria, the activity of which is beneficial to crops, may fail to flourish because the food supplied them is not suitable or because their own products or the products of other forms hinder their growth. On the other hand, the activity of harmful bacteria, fungi, or protozoa may be stimulated by an abundant supply of suitable food. The necessity then of some chemical knowledge of this culture medium and by-products,

in any study of the mutual relation of soil microörganisms to each other or to crops, is apparent.

The properties of soils generally included under the term physical, such as water-holding power, heat conductivity, absorption, granulation, are universally recognized as potent factors in determining the character of a soil and its adaptability to the growing of crops. In considering these factors the tendency has been to consider the soil simply as an aggregate of mineral particles of different sizes and consequently different surface area, and to correlate the varying physical properties with this variation. That this view is wholly inadequate is evident, for solid organic matter may also be present in particles of different sizes and these may have different physical properties due not only to variation in size, but probably much more so to difference in chemical composition and structure. Furthermore, the organic matter may and in fact generally does play an intimate part in the behavior of the mineral particles entering into chemical combination, coating them or cementing them together. It is evident then that there can be intelligent study of the influence that the organic matter of the soil has on its physical properties only when the chemical identity of its several components is known.

The great majority of organic chemical compounds are re- · active toward inorganic compounds, acids, bases, and salts. Organic acids can form salts with mineral bases, or double salts with mineral salts. Organic bases form salts with mineral acids and quite a number of organic compounds combine both acid and basic properties and form organic compounds with both mineral acids and bases. Such being the case, there necessarily exists a mutual relation between the organic compounds in the soil and the mineral particles which form its foundation. Some of the acids isolated from soils could not exist free for any time in a soil containing free bases or salts of weak acids such as carbonic acid, and there is abundant evidence that many of the organic compounds exist in the soil in mineral combination. In fact, the relation between the organic and mineral particles of the soil is so intimate that any differentiation of soil chemistry into organic and inorganic should not be used as the basis of any theory or line of argument regarding soil phenomena or soil treatment.

TABLE I.

Method of separation.	Class.	Compound isolated and identified.
Alkaline extract — Humus precipitate — Soluble in alcohol — Soluble in petroleum ether — Insoluble in cold alcohol	Acids	α—Hydroxystearic acid.[1] Paraffinic acid.[2]
Soluble in cold alcohol	Acids / Fats	Liquid glycerides.[3]
Insoluble in petroleum ether	Resinous bodies	Resin acids. Resin esters.
Insoluble in alcohol — Shaken out by ether — Precipitated by ether	Acids	Dihydroxystearic acid.[4]
Precipitated by silver nitrate in neutral solution	Acids	Picoline carboxylic acid.
Precipitated by silver nitrate in alkaline solution	Pyrimidine derivatives	Cystosine.[5]
Acid filtrate — Precipitated by lead acetate in alkaline solution	Hexone bases	Histidine.[7] Arginine.[8]
Precipitated by copper sulphate and sodium bisulphite	Pentosan	Xylan.[9]
	Purin bases	Xanthine.[10] Hypoxanthine.[11]
Hot alcohol extract — Insoluble in cold alcohol, saponified — Soluble in petroleum ether — Insoluble in cold alcohol	Hydrocarbons	Hentriacontane.[12]
Soluble in cold alcohol	Cholesterol compounds	Phytosterol.[13] Agrosterol.[14]
Soluble in cold alcohol — Water soluble — Insoluble in petroleum ether	Acids	Agroceric acid. Lignoceric acid.[15]
Water insoluble — Ether insoluble — Ammonium carbonate soluble	Resinous bodies	Resin acid I.
Sodium carbonate, soluble	Resinous bodies	Resin acid II.
Sodium hydrate, soluble	Resinous bodies	Resin acid III.
Undissolved	Resinous bodies	
Ether soluble	Resinous bodies	Resin ester.

[1] Jour. Am. Chem. Soc., xxxii, 1674 (1910); [2] idem, xxxii, 1677 (1910); [3] idem, xxxiii, 78 (1911); [4] idem, xxx, 1599 (1908); [5] idem, xxx, 1295 (1908); [6] Jour. Biol. Chem., viii, 389 (1910); [7] idem, viii, 381 (1910); [8] idem, 383, viii, (1910); [9] Jour. Am. Chem. Soc., xxxii, 1680 (1910); [10] Jour. Biol. Chem., viii, 391 (1910); [11] idem, viii, 392 (1910); [12] Jour. Am. Chem. Soc., xxxiii, 81 (1911); [13] Jour. Biol. Chem., (1911); [14] Jour. Am. Chem. Soc., xxxi, 116 (1909); [16] Jour. Am. Chem. Soc., xxxii, 1679 (1910).

With a recognition of the importance of a more thorough knowledge of the chemical nature of the organic matter of soils, the Division of Fertility Investigations of the Bureau of Soils has been carrying on a research dealing with this material largely by biochemical methods; methods which have heretofore been used in the isolation and identification of organic compounds from plant or animal tissues or other methods devised along similar lines.[1]   The result of this work so far is that twenty definite organic compounds have been isolated from that portion of the soil organic matter included in the term humus. These compounds comprise eight classes: paraffin hydrocarbons, acids, alcohols, esters, carbohydrates, hexone bases, pyrimidine derivatives, and purin bases being represented. Some of these, such as purin bases, pyrimidine derivatives, and hexone bases, have been isolated by methods well-known and in common use by biochemists. Others for which no method existed or which from the nature of the material required special treatment, have been obtained by methods devised for the purpose but all founded on the ordinary technic of biochemical work.

The method by means of which the isolation of the substances from the organic matter of soil was accomplished may be briefly shown in the accompanying schematic representation (Table I), although for actual working details the individual journal articles must be consulted.

From the work so far accomplished it has been shown that the organic matter of soils is made up of a large number of organic compounds, a great majority of the classes of compounds found in plants and animals being represented.

The conclusion seems warranted that while this material is very complex and the character of only a portion of it is at present understood, the complexity is not so great, but that by the application of biochemical methods of research, the chemical nature of the whole of it may ultimately be established.

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[1] See especially Bulletins 53 and 74, Bureau of Soils, U. S. Department of Agriculture, for details in this connection.

NOTES ON THE HISTORY OF BALLOON PHOTOGRA-
PHY.

EDWARD DOLEZAL,

Extraordinary Professor in the Royal Imperial High School in Vienna.

THE well-known French writer, A. Davanne, for a long while the president of that highly distinguished society, the " Société Française de Photographie " in Paris said in an address : " The world will never forget that to France is due the invention of photography and the promulgation of its method."

In August, 1909, seven decades had elapsed since the French scientists, Arago and Gay Lussac, after a searching investigation of the process of painter Daguerre and cavalry officer Niepce, by which pictures could be taken by light, recommended the purchase of the rights thereto by the French government. The purchase was made and through the liberality of the government, Arago was able on August 29, 1839, to make known the methods at a public session of the Academy of Sciences.

Arago's foresight was sufficient to indicate to him the value of the method in connection with the preparation of maps and charts, but he did not foresee its use in connection with balloon work. The latter application originated with a Frenchman named Andraud, who in an essay,—" Une derniére annexe au Palais de l'Industrie," expressed some views on balloon photography, in which, indeed, he allowed his fancy to play in almost the style of Jules Verne. The merit of taking the first balloon photograph belongs to a Paris photographer and aeronaut, Nadar senior. His experiments showed, as was to be expected, that the photographic procedure of that day,—wet plates and prompt development,—involved serious difficulties. Nadar installed a dark room in the basket of the balloon in the form of a tent of orange stuff with black lining. It appears however, that the carbon disulphide in the gas affected his plates. He did not lose hope. At " Petit Bicêtre" a hamlet consisting

only of a dairy-farm, a tavern and small barracks, he pre-
pared his plates, rose quickly to the height of about 80 metres
in a captive balloon, returned and developed the pictures.   Nadar
having thus shown the practicability of such photography, was
invited in 1859 by the Italian minister of war to test his method
in connection with the war with Austria, but the results, espe-
cially at Solferino, did not meet expectations.

In spite of these failures, balloon photography found new
disciples in Europe and in the new world.   In 1860, King and
Black made such photographs in the neighborhood of Boston,
U. S.; an Italian, Negretti, at the instance of King Victor Em-
manuel I, succeeded in taking pictures from a free-moving
balloon, and in the American Civil War, Lowe obtained views
which served as guides for important military operations.

Nadar anticipated great results from his experiments, took out
many patents and also published articles, his views being oc-
casionally fantastic.   In 1868, he resumed his experiments in
Paris, using a captive balloon furnished by Henry Giffard, with
which he reached a height of 200 metres and took a picture
showing the triumphal arch, and other important structures.   This
negative is still to be seen in the collection of the Conservatoire
des Arts et Métiers in that city.   It marks a material progress
in the art.

No important results in balloon photography were reported
during the Franco-Prussian War, and the subject seemed to be
neglected until 1878 when the Paris photographer, Dagron, took
it up with much energy and obtained, with a captive balloon,
a striking picture of Paris on a negative 22 x 28 cm. (about 9 x
12 inches).   Dagron used a basket dark-room as Nadar had done.

With the discovery of the dry-plate method by the English
physician Maddox a new era began for balloon photography.
Triboulet, an architect, and an enthusiastic promoter of meteor-
ologic investigations, was the first to use the dry-plate in a
free-moving balloon.   On June 8, 1879 he ascended in the
balloon Jovis from a hamlet near Paris, the photographic ap-
paratus being fastened to the side of the basket.   At a height of
500 metres above the Paris observatory, he took a panoramic
picture, but scarcely had this been made when a cloudburst oc-
curred that compelled him to descend although he had thrown
out all available ballast.   Unluckily, his balloon struck one of

the Notre-Dame towers and he subsequently came down in the Seine. As the balloon was an unusual visitor to the city, a zealous custom-officer followed it—on foot it seems—and when the balloonist reached the shore insisted upon a thorough search of all the packages and so in spite of the protests of the experimenter, the dark slide had to be opened and the picture was ruined.

In 1880, Desmaret succeeded in a free-moving balloon in taking pictures 21 x 27 cm. using a lens of 29 cm. focus and regulating the duration of exposure by electrical apparatus. He had also in his basket accurate barometers, and regulated the exposure according to the speed of the balloon. He used highly sensitive plates. Two of his negatives are to be seen in the Conservatoire des Arts et Métiers. In 1882, Shadbolt of England did good work in this field.

Attention now began to be directed to the construction of apparatus especially adapted to balloon photography, the methods heretofore followed having been merely the attaching of ordinary cameras to the basket. In 1881, Woodbury of England constructed a camera for automatic photography from a captive balloon but it was not a success. In 1884 Triboulet built an apparatus consisting of seven cameras so arranged that when suspended beneath the basket they formed an inverted arch and by an electrical connection the whole series could be snapped at once and thus a wide field photographed.

The evident advantage that such photography might give in war led all the active European nations to take up the subject now that good results seemed possible and Tissander, Ducom and Renard in France, Eleslade and Templar in England, von Tschudi, von Hagen and von Sigsfeld in Germany, Thiele and Uljanin in Russia, Ranza in Italy and Speltrini in Switzerland are among those who labored in developing the methods. Ranza invented a form of captive balloon specially adapted for photographic work and materially advanced the technic of the art. Speltrini was the first to cross the Alps in a balloon and he secured striking pictures of the mountain peaks.

Victor Silberer was the first to carry out balloon photography in Austria. In 1885 he took a picture of the Reichsbruecke in Vienna. Silberer also organized and conducted the first military school for aeronautics, and he carried the work to such a point that it became entirely suitable for strategic purposes.

FRANKLIN INSTITUTE

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 15, 1911.

PRESIDENT WALTON CLARK *in the Chair.*

Additions to membership since last report, 7.

The standing Committees for the year 1911-12 were announced.

The President called attention to the fact that Colonel George W. Goethals, U. S. A., Chief Engineer of the Isthmian Canal Commission, would address the Engineers' Club, on the " Panama Canal " this evening and that the members of the Institute are invited to attend.

On motion the invitation was accepted, the programme arranged for this meeting was postponed, and the members adjourned to the Engineers' Club.

R. B. OWENS,
Secretary.

STANDING COMMITTEES 1911.

Of the Board of Managers.

INSTRUCTION.

Lawrence T. Paul, *Chairman.*
G. A. Hoadley,
E. V. McCaffrey,
Charles Day,
J. S. Rogers,
R. B. Owens, *ex officio.*

EXHIBITIONS.

John Birkinbine, *Chairman,*
James Dodge,
E. H. Sanborn,
W. C. L. Eglin,
C. A. Hexamer.

STOCKS AND FINANCE.

Walton Forstall, *Chairman,*
R. W. Meirs,
E. H. Sanborn,
A. C. Harrison,
Treasurer of the Institute.

ELECTIONS AND RESIGNATIONS OF MEMBERS.

W. C. L. Elgin, *Chairman,*
Otto C. Wolf,
Walter Wood,
Alex. P. Robinson,
Alexander Krumbhaar.

Publications.

Louis E. Levy, *Chairman,*
John Birkinbine,
E. H. Sanborn,
James Christie,
Edwin S. Balch,
R. B. Owens, *ex officio.*

Endowment.

Henry Howson, *Chairman,*
James M. Dodge,
Coleman Sellers,
A. C. Harrison,
R. W. Meirs.

Sectional Arrangements.

James Christie, *Chairman,*
C. E. Ronaldson,
Lawrence T. Paul,
W. C. L. Eglin,
E. Goldsmith,
R. B. Owens, *ex officio.*

Of the Institute.

Library.

Edwin S. Balch,
Richard Gilpin,
Lewis M. Haupt,
Carl Hering,
H. F. Keller,
Henry Leffmann,
Louis E. Levy,
C. E. Ronaldson,
George F. Stradling,
John C. Trautwine, Jr.

Meetings.

G. S. Barrows,
James Christie,
G. H. Clamer,
Kern Dodge,
Lewis M. Haupt,
H. A. Hornor,
J. Y. McConnell,
James S. Rogers.
Coleman Sellers,
W. J. Williams,

Museum.

A. A. Blair,
R. H. Bradbury,
Charles Day,
E. Goldsmith,
W. H. Greene,
Geo. A. Hoadley,
E. V. d'Invilliers,
Harry F. Keller,
A. E. Outerbridge,
Wm. H. Thorne.

REPORT OF THE COMMITTEE ON STOCKS AND FINANCE FOR THE YEAR 1910.

To the Board of Managers:

Financial Statement, October 1, 1909 to September 30, 1910.

PROPERTY AND FUNDS.

Building and land, 13–17 S. Seventh Street..........	$44,000.00	
Library	100,000.00	
Apparatus, collections and models.................	5,022.49	$149,022.49

	Principal	Unexpended Income
Funds held by Board of Trustees........	$63,310.28	$770.25
Funds held by Board of Managers........	23,478.50	767.77
Franklin Fund	341,967.42	
Elliott-Cresson Medal Fund.............	1,000.00	3,156.20
Franklin Fund and Building Committee....	4,689.97	

Total funds $434,446.17	$4,694.22	$439,140.39
Grand total			$588,162.88

LIABILITIES.

Certificates of Stock..$31,210.00	
Mortgage on Institute Building (held by Trustees as investment for Funds)....................................	3,575.00
Bills payable	20,250.00
Life memberships	3,835.00
Accounts payable	3,432.69
Unearned income	658.96

Grand total $62,961.65	

INCOME AND EXPENSES APPLICABLE TO YEAR ENDING SEPTEMBER 30.

INCOME.

Dues	$8,791.67
Initiation fees	90.00
General endowment fund........................	2,223.32
Estate of John Turner..........................	104.98
Estate of Robert Wright........................	2,097.24
Miscellaneous	17.97
Membership badges	4.00
Instruction: Machine design	309.06
Publications: Subscriptions and sales...........	1,665.74
Publications: Advertising	2,844.21
Total $18,148.19	

EXPENSES.

Building: Wages	$843.30	
Repairs and maintenance....................	151.37	
Heat, light and power.......................	717.15	
Taxes, water rent and insurance............	472.79	
Miscellaneous supplies and expenses..........	498.89	$2,683.50
Elections and Resignations............................		129.45
Instruction: Drawing School	$36.60	
Naval Architecture	30.36	
Popular Lectures	652.54	719.50
Library: Salaries	$2130.75	
Books and Periodicals........................	1525.38	
Binding	870.25	
Miscellaneous expenses	299.46	4,825.84
Meetings		225.93
Office and General: Salaries..........................	$5270.27	
Office expense	245.26	
General expense..................	1101.65	6,617.18
Publications: Printing	$3251.31	
Reprints	192.45	
Illustrations	286.12	
Miscellaneous Expense....................	219.44	3,949.32
Science and Arts..		222.81
Sections		445.64
Interest and Discount..		799.59
Frederic Graff Rebuilding....................................		120.29
Interest paid John T. Kille on donation to General Endowment Fund		200.00
Total		$20,939.05
Net expense..		$ 2,790.86

During the year, the General Endowment Fund has been increased by $280.16, through bequest from the Estate of James Neumann. The building Fund of the Board of Trustees has been merged into the Franklin Institute Building Fund. Of the Elizabeth M. Graff Fund, $4000 has been devoted to renovating the Institute building. The Franklin Institute Building Fund has been increased over $10,000, through interest accretions. Certificates of Stock, First Class, have decreased by $4310, chiefly due to donations of stock in return for memberships. The mortgage on the Institute building has been reduced by $750. $2050 of notes given in payment of deficit subscriptions have been cancelled by holders.

The excess of expenses over income for the year was $2790.86. This was entirely due to expenses required to broaden the influence of the Institute, and to place it once more in a position where an increased membership will furnish an income adequate to its needs.

Respectfully submitted,

WALTON FORSTALL,
Chairman.

PHILADELPHIA, PA., January 11, 1911.

REPORT OF COMMITTEE ON ELECTIONS AND RESIGNATIONS OF MEMBERS.

To the Board of Managers:

During the Fiscal Year (October, 1909, to September, 1910, incl.), there were elected to membership, 54 resident members, 19 non-resident members, 5 associate members and 4 life members.

During the same period, there were resignations from 29 resident members, and 17 non-resident members, and deaths were recorded of 3 resident members, 2 non-resident members, 2 life members, 1 second-class stock member and 1 honorary member.

Respectfully submitted.

W. C. L. EGLIN,
Chairman.

PHILADELPHIA, PA., January 11, 1911.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting, held Wednesday, February 1, 1911.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 1, 1911.

MR. THOMAS SPENCER *in the Chair.*

Dr. George A. Hoadley was elected chairman for the year 1911–12.

In the absence of a quorum the reports for final action were not considered.

The following reports were presented for first reading:

No. 2461.—Shore's Scleroscope.

No. 2494.—Seley's Steel in the use of freight car construction (Advisory). Adopted.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Physics and Chemistry.—The stated meeting of the Section was held on Thursday, January 26, 1911, in the Hall of the Institute, at 8 P.M., with Dr. Robert H. Bradbury, President of the Section in the Chair.

One hundred and twenty-five members were present.

The minutes of the previous meeting were approved as read.

Dr. Harry F. Keller, Professor of Chemistry and head of the Department of Science in the Central High School of Philadelphia, delivered a lecture upon the " Use of Lantern Slides in the Teaching of Chemistry." He emphasized the value of lantern slides as an adjunct in the teaching of chemistry, but strongly recommended that pictures of an experiment should supplement but never replace the experiment itself in a lecture upon general chemistry.

Dr. Keller described the large and valuable collection of slides bearing upon chemistry which he has collected in the Central High School. This collection falls into four grand divisions: historical, general, industrial and special.

The historical portion consists of portraits of famous chemists, their apparatus and laboratories; the general division comprises pictures of apparatus and experiments relating to general chemistry, the industrial slides illustrate the various applications of chemistry in the arts. The special division contains slides prepared especially for certain lectures such as Chemists' Workshops Old and New, Illumination, etc. The collection as a whole is one of the best in America, and the historical portion is without a peer upon this continent.

The lecture was illustrated with the gems of the collection. A vote of thanks was tendered Dr. Keller, and the meeting adjournd.

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JOSEPH S. HEPBURN,

Secretary.

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Electrical Section.—A meeting of the Section was held on Thursday, February 2, 1911, at 8 P.M.

Mr. Thomas Spencer in the Chair. Fifty members and visitors present.

After the reading and approval of the minutes of the previous meeting the Chairman introduced Mr. F. G. Vaughen, of the General Electric Company, Schenectady, New York, who read a paper on " Prepayment Electric Meters." The speaker outlined the history of coin-controlled devices and referred especially to the design, construction, and requirements of a good Prepayment Electric Meter. The subject was fully illustrated by lantern slides. A lengthy discussion followed the reading of the paper in which Mr. Snook, Mr. Green, Dr. Owens, the Chairman and others took part. On motion a vote of thanks was tendered the speaker and his paper was referred to the Committee on Publications. Adjourned.

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R. B. OWENS,

Acting Secretary.

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Mining and Metallurgical Section.—A meeting of the Section was held on Thursday evening, February 9, at 8 o'clock. In the absence of the regular officers of the Section the Librarian of the Institute introduced Dr. Edgar T. Wherry, of Lehigh University, South Bethlehem, Pa., who presented a report on the " Eleventh International Geological Congress held at Stockholm, Sweden, during the Summer of 1910."

Dr. Wherry represented the Institute at the deliberations of this Congress and his report outlined the work of the organization and the various geological excursions which preceded and followed the meetings. He gave an interesting account of the metals, mines and mineral deposits of Sweden and Norway.

The subject was fully illustrated by lantern slides made from original photographs of many subjects relating directly or indirectly to the Congress and to the metallurgical work and mines of Scandinavia.

Section of Physics and Chemistry.—The Stated Meeting of the Section was held in the Hall of the Institute on Thursday, February 16, 1911, at 8 p.m., with Dr. R. B. Owens in the Chair.   Forty-two members and visitors were present.

The minutes of the previous meeting were read and approved.   Mr. L. S. Dow, of the H. J. Heinz Company, Pittsburg, Pa., delivered an address upon Modern Commercial Food Manufacturing.   The various methods were discussed which have been used from prehistoric times for the preservation of foodstuffs, including smoking, salting, sterilization and the use of chemical antiferments.   The statement was made that by the use of cleanly methods of preparation, followed by sterilization, perishable foodstuffs may be preserved without the use of chemicals.   The lecture was illustrated with lantern slides depicting the growing and preserving of vegetables, the preparation of olive oil and the manufacture of cider vinegar.   The paper was referred for publication, a vote of thanks was given to Mr. Dow, and the meeting adjourned.

JOSEPH S. HEPBURN,

Secretary.

MEMBERSHIP NOTES.

Elections to Membership.

RESIDENT.

MR. J. A. P. CRISFIELD, 1405 Arch Street, Philadelphia, Pa.
MR. H. A. HORNOR, New York Ship Building Co., Camden, N. J.
MR. M. M. PRICE, Babcock & Wilcox Co., 1010 North American Building, Philadelphia.
MR. GEORGE L. THOMPSON, General Electric Company, Witherspoon Building, Philadelphia.

DR. CLAYTON H. SHARP, Electrical Testing Laboratories, 80th St. and East
End Ave., New York City.
MR. F. G. VAUGHEN, General Electric Co., Schenectady, N. Y.

ASSOCIATE.

MR. JOSEPH SHALLCROSS WEBB, Swarthmore College, Swarthmore, Pa.

Changes of Address.

MR. W. H. GARTLEY, P. O. Box 1902, Philadelphia.
MR. D. E. MAXFIELD, 6 West Oak Ave., Moorestown, N. J.
HON. EDWARD MORRELL, Morris Building, 1421 Chestnut Street, Phila.
MR. F. R. PLEASONTON, P. O. Box 102, Steelton, Pa.
MR. MARRIOTT C. SMYTH, 1700 Morris Building, Philadelphia.
MR. EDWIN D. TUCKER, 39-41 West Twenty-third Street, New York City.

NECROLOGY.

Mr. R. Winder Johnson, 209 S. Third Street, Philadelphia.
Mrs. Clara E. Stewart, The Gladstone, Eleventh and Pine Sts., Philadelphia.

LIBRARY NOTES.

Purchases.

American Civil Engineers' Pocket-Book.
PETIT. R.—How to Build an Aeroplane.
BERGET, A.—The Conquest of the Air.
MOOREHEAD, W. K.—The Stone Age in North America.
POYNTING, J. H.—The Pressure of Light.
SMILES, S.—The Relations Between Chemical Constitution and Some Physical
Properties.
JOHNSON, G. L.—Photographic Optics and Colour Photography.
A History of the Cavendish Laboratory, 1871-1910.
PLANCK. M.—Das Prinzip der Erhaltung der Energie.
WHITAKER, J.—Almanac for 1911.
SPITTA, E. J.—Microscopy.
British Journal Photographic Almanac for 1911.
SEATON, A. E.—The Screw-Propeller.
BREWER, R. W. A.—The Art of Aviation.
Nelson's Perpetual Loose-leaf Encyclopædia, 12 vols.
CAJORI, F.—A History of the Logarithmic Slide-rule.
HALL, H, R.—Governors and Governing Mechanism.
PIERCE, G. W.—Principles of Wireless Telegraphy.

Gifts.

Iowa Railroad Commissioners. Thirty-second Annual Report for 1909. Des
Moines, 1910. (From the Commission.)

Pennsylvania Topographic and Geologic Survey Commission Report No. 3.
Harrisburg, 1910. (From the State Librarian.)

Mysore Meteorological Department. Report on Rain-fall Registration for
1909. Bangalore, 1910. (From the Department.)

American Institute of Electrical Engineers. Yearbook for 1911. New York,
1911. (From the Institute.)

Iron and Steel Institute Journal 1910, Part 2. London, 1910. (From the
Institute.)

Yale University Catalogue for 1910–1911. New Haven, 1910. (From the
University.)

Oklahoma Geological Survey. Bulletin No. 6. Norman, 1910. (From the
Survey.)

American Mining Congress. Report of the Proceedings of the Thirteenth
Annual Session held at Los Angeles, California, September 26 to Oc-
tober, 1 1910. Denver, 1910. (From the Congress.)

Interstate Commerce Commission. Twenty-second Annual Report on the
Statistics of Railways in the United States for the year ending June 30,
1909. Washington, 1910. (From the Commission.)

United States Naval Observatory, Publications, vol. 4. Parts 1 to 4. Wash-
ington, 1906. (From Hon. J. Hampton Moore.)

Manchester Municipal School of Technology Journal, volume 3 of 1909.
Manchester, 1910. (From the Education Committee.)

Great Britain Labour Department. Fourth Abstract of Foreign Labour
Statistics. London, 1911. (From the Department.)

Boston Transit Commission. Sixteenth Annual Report, 1910. Boston, 1910.
(From the Commission.)

Canadian Mining Institute Journal, vol. 13, 1910. Montreal, 1911. (From
the Institute.)

New York State Education Department. Annual Report for 1910, vols.
2 and 3. Albany, 1910. (From the New York State Library.)

Philadelphia—A Periodical, vols. 1, 2, 3—1909–1910. Philadelphia, 1910.
(From the City of Philadelphia.)

Wisconsin—Report of the State Forester for 1909, 1910. Madison, 1910.
(From the State Board of Forestry.)

Liverpool Literary and Philosophical Society—Proceedings No. 61. Liver-
pool, 1910. (From the Society.)

Tasmania—Geological Survey, Bulletin No. 8, with Geological Maps and
Mine Plans. Hobart, 1910. (From the Survey.)

London Meteorological Office—Meteorological Observations at Stations of
the Second Order for 1907. London, 1910. (From the Office.)

Rendiconto delle Sessioni della R. Accademia delle Scienze dell'Institutio di
Bologna. Classe di Scienze Fisiche, Nuova Serie, vol. xiii, 1908–1909.
Bologna, 1909. (From the Institute.)

Memorie della R. Accademia delle Scienze dell'Instituto di Bologna. Classe di Scienze Fisiche. Serie vi, Tomo vi, 1908–1909. Bologna, 1909. (From the Institute.)

Atti del R. Instituto d' Incoraggiamento di Napoli. Serie Sesta, 1909, vol. 61. Napoli, 1910. (From the Institute.)

Michigan State Board of Agriculture, Forty-ninth Annual Report of the Secretary. July 1909 to June, 1910. Lansing, 1910. (From the State Board.)

India Weather Review. Annual Summary, 1909. Simla, 1910. (From the Meteorological Department.)

Lake Superior Mining Institute—Proceedings, vol. 15, 1910. Ishpeming, 1910. (From the Institute.)

Congressional Directory, 61st Congress, 3rd Session, 1st and 2nd Editions, December, 1910, and January, 1911. Washington, D. C., 1910–1911. (From the Superintendent of Documents.)

Pennsylvania Department of Forestry, Report for the Years 1908–1909. Harrisburg, 1910. (From the Department.)

Smithsonian Institution. Report for 1909. Washington, 1910. (From the Institution.)

BOOK NOTICE.

QUESTIONED DOCUMENTS. A Study of Questioned Documents with an Outline of Methods by which the Facts May Be Discovered and Shown. By Albert S. Osborn, Examiner of Questioned Documents, with an introduction by Professor John H. Wigmore, author of "Wigmore on Evidence." 8vo, cloth, xxiv + 501 pages with 200 illustrations. Price, $5.25. Lawyers' Coöperative Publishing Company, Rochester, N. Y., 1910.

The paramount importance of establishing the genuineness or fraudulence of documentary records is indisputable. Handwriting is one of the few modes of permanently recording a transaction along with the imprint of the personality of the maker thereof. It is a matter of common observation that a person's signature varies comparatively little even after a considerable lapse of time. It is not so evident, but becomes so on close study, that there are certain characteristics unconsciously produced which are well-nigh non-concealable and that positively identify this origin.

Much effort in recent times has been devoted to a study of these characteristics and to the other features as well that govern the conditions and form of written documents. The results of such researches have been of inestimable value particularly in cases of legal inquiry. The duty of an expert witness entrusted with the investigation of a disputed document upon which important issues may depend is an extremely responsible one and he must be not only fully qualified as to scientific attainment but his mode of procedure should be reduced to a code of practice that will with certainty lead to accurate and fully verified results.

Mr. Osborn's work is a treatise developing the subject in a manner conducive to that end. The expert employing his methods will be prepared, in presenting his views, to sustain them with adequate demonstrations. The best mode of handling documents, their peculiarities, how made apparent and identified as well as a multiplicity of other features disclosed by chemical and physical methods are described at great length. Well executed reproductions of specimens of writing in natural size with photographic enlargements show clearly the utility of the photographic camera in such investigations. The illustrations of the apparatus employed in position for use add much to the value of the work for any one studying the subject with a view to practically applying it.

Many of the methods and processes have been described by a late member of the Franklin Institute, Dr. Persifor Frazer, who was deeply interested in the study of documents and published the results of his labors in that direction under the name " Bibliotics " in 1901. The extensive bibliography at the end of the volume indicates that many others have also worked in the same field, but the lack of fundamental originality does not detract from the decided merit of a book presenting an illuminating and unusually well illustrated account of the most efficient means of applying what has been accomplished in the study of questioned documents.

PUBLICATIONS RECEIVED.

A course in Qualitative Chemical Analysis. By Charles Baskerville, Ph.D., F.C.S., Professor in the Department of Chemistry, College of the City of New York, and Louis J. Curtman, Ph.D., Instructor in the Department of Chemistry, College of the City of New York. 200 pages, 8vo. New York: Macmillan Co., 1910. Price in cloth, $1.40.

Motion Study—A Method for Increasing the Efficiency of the Workman. By Frank B. Gilbreth, Member of the American Society of Mechanical Engineers. With an introduction by Robert Thurston Kent, Editor of Industrial Engineering. 116 pages, 12vo. New York: Van Nostrand Co., 1911. Price, in cloth, $2.00.

U. S. Department of Interior. Bureau of Mines, Bulletin 4. Features of Producer-gas Power-plant Development in Europe. By R. H. Fernald. 27 pages, plates, 8vo. Washington, Government Printing Office, 1911.

U. S. Department of Interior. Bureau of Mines. Miner's Circular 2. Permissible Explosives Tested Prior to January 1, 1911, and Precautions to be Taken in Their Use. By Clarence Hall. 12 pages, 8vo. Washington, Government Printing Office, 1911.

Library of Congress. Publications of the Library Issued Since 1897. 45 pages, 12mo. Washington, Government Printing Office, 1911.

University of Missouri School of Mines and Metallurgy, Bulletin, December, 1911. 39 pages, 8vo. Rolla, Missouri, n.d.

Hygiene, Offizielle monatsschrift der Internationalen Hygiene-Ausstellung, No. 1, January, 1911. 16 pages, illustrations, 4to. Dresden, 1911.

Wisconsin Engineer. February, 1911. Vol. 15, No. 5. Madison, Wisconsin Engineering Journal Association, 1911.

Allen's Commercial Organic Analysis. A treatise on the properties, modes of assaying, and proximate analytical examination of the various organic chemicals and products employed in the arts, manufacture, medicine, etc., with concise methods for the detection and estimation of their impurities, adulterations, and products of decomposition. Vol. 4. Resins, india-rubber, rubber substitutes and gutta-percha, hydrocarbons of essential oils, ketones of essential oils, volatile or essential oils, special characters of essential oils, tables of essential oils by the editors and the following contributors: M. Bennett Blackler, E. W. Lewis, T. Martin Lowry, Ernest C. Parry, Henry Leffmann, Charles H. LaWall. Fourth edition, entirely rewritten. Edited by W. A. Davis, B.Sc., and Samuel S. Sadtler, S.B. 466 pages, illustrations, 8vo. Philadelphia, P. Blakiston's Son & Co., 1911. Price, cloth, $5.00.

CURRENT TOPICS

Production of Spelter in 1910.—*Gratifying Growth of the Zinc Industry.*—The annual preliminary statement just issued by the United States Geological Survey shows that so far as production and consumption are concerned the spelter industry of the country enjoyed a year of continued normal growth. The total production of spelter in the United States in 1910 broke all records; the production from domestic sources alone exceeded the total production for any previous year in the history of the industry and exceeded the domestic production for any other year by 20,000 tons. Coupled with this increase in production there was a decrease in imports and at the same time exports were more than quadrupled.

The following figures have been compiled without change by C. E. Siebenthal, of the Geological Survey, from reports furnished by all operating smelters of zinc ores, showing their output for the first eleven months of the year and their estimated production for December. Figures showing the imports and exports for eleven months were obtained from the Bureau of Statistics and to these figures estimates for December have been added.

Production.—The production of primary spelter from domestic ore in 1910 is estimated at 250,052 short tons and from foreign ore at 17,371 tons, a total of 267,423 tons, worth, at the average price, $28,881,684, as compared to a total of 255,760 tons in 1909, made up of 230.225 tons of domestic origin and 25,535 tons of foreign origin. The production of spelter from both domestic and foreign ores, apportioned according to the States in which the ores were smelted, was approximately as follows: Illinois, 73,373 tons in 1910 and 67,653 tons in 1909; Kansas, 105,659 tons in 1910 and 103,299 tons in 1909; Oklahoma, 34,762 tons in 1910 and 28,782 tons in 1909; all other States, 53,629 tons in 1910 and 56,026 tons in 1909. The total production of spelter is equivalent to the output of 61,700 average retorts operating continuousuly through the year, or about 70 per cent. of the maximum capacity of the smelting plants in operation for some part of 1910.

Imports and Exports.—The imports of zinc ore fell off over 25 per cent. They were approximately 85,084 short tons, containing about 83,000,000 pounds of zinc and worth, as invoiced, about $888,000; 116,269 tons of zinc ore were imported in 1909. The figures for 1910 do not include 10,431 short tons of lead ore from South America, containing 2,645,111 pounds of zinc, an average of less than 13 per cent., all of which was lost in smelting the lead and thus does not properly enter into the figures of im-

ports of zinc. Of the zinc ore imported, 80,309 tons, or 90 per cent., came from Mexico, as compared with 106,245 tons imported from Mexico in 1909. The exports of zinc ore for the first eleven months of 1910 were 17,558 short tons, valued at $570,510, as compared with 12,455 tons in 1909.

Imports of spelter were decreased over half, being estimated at 3339 short tons, valued at $282,653, as compared with 9670 tons in 1909. Exports of domestic spelter increased over 50 per cent., being estimated at 3953 short tons, valued at $424,172, as compared with 2566 tons in 1909. The establishment of zinc smelting in bond increased the exports of foreign zinc from their previously insignificant proportions to approximately 5029 short tons, valued at $196,250, in 1910. During the first nine months of the year there were also exported, under drawback, articles manufactured from 2717 tons of foreign spelter on which duty had been paid. The exports of zinc dross amounted to 4675 short tons, valued at $377,000, as compared with 7069 tons in 1909.

Consumption.—The apparent domestic consumption of spelter in 1910 may be computed as follows: The sum of stock on hand at smelters at the beginning of the year, 11,167 tons, plus the imports, 3339 tons, and the production, 267,423 tons, gives the total available supply, 281,929 tons. From this are to be subtracted the exports of domestic spelter, 3953 tons; the exports of foreign spelter, 5029 tons; the exports under drawback, 2717 tons; and the stock on hand at smelters at the close of the year (to be exact, on hand December 15), 20,170 tons, a total of 31,869 tons, leaving a balance of 250,060 tons as the apparent domestic consumption, almost exactly the production from domestic ores. This calculation takes no account of the stocks of spelter held by dealers or consumers. On comparing the apparent consumption in 1910 with the 271,274 tons in 1909 the 215,401 tons in 1908, and the 228,524 tons in 1907, it is seen to be about normal, indicating that stocks other than those at smelters have at least not greatly increased during the year.

Prices.—Spelter opened at St. Louis in January at 6.05 to 6.075 cents a pound, the highest price of the year, and declined until the middle of June, when the minimum for the year was reached at 4.925 cents a pound. During the latter part of the year the price made a considerable recovery, reaching 5.90 cents in the middle of November, but afterward a decline set in and the year closed with spelter around 5.3 cents a pound. The average St. Louis price of prime western spelter was the same as for 1909— 5.4 cents a pound.

The Inspection of Castings. J. A. GEARHEART. (*Iron Age,* lxxxvi, 1142.)—A detailed description of an Inspector's duties and how they should be carried out. This article will be of interest to manufacturers, users, and inspectors of castings.

The Magnetic Properties of Iron and its Alloys in Intense Fields. R. A. HADFIELD AND B. HOPKINSON. (*Engineering, London,* xc. 835.)—An investigation which appears likely in the future to furnish data and a method of experiment which will be of assistance in research work on the physical constitution of iron and iron alloys is being carried out by Sir Robert A. Hadfield and Professor Bertram Hopkinson. The investigation is concerned with the magnetic properties of these materials in intense fields, and there is a singular appropriateness in the fact that the actual magnetic testing is being carried out by Professor Hopkinson at Cambridge, since the investigation is, in a measure, an extension and development of Ewing's pioneer work on magnetism. Some account of the results which have been so far obtained was presented in a paper by Sir Robert Hadfield and Professor Hopkinson, read before the Institution of Electrical Engineers.

The investigation was undertaken to determine the relation between the magnetizing force and the flux density in the H and B, of magnetic materials, in intense fields. In the moderate fields employed in practice the relation between these two quantities is complicated and dependent on many variables, but in intense fields this relation assumes a very simple form. According to Ewing's molecular theory of magnetism it may be supposed that in moderate fields the relation between H and B is a function of the interactions between the individual molecules, and that the molecular configuration which results in such fields is dependent largely on external conditions and on the previous history of a material; but in intense fields it may be assumed that the molecular configuration taken up is determined only by the magnetizing force, as this is strong enough to entirely swamp the effect of interactions between the molecules, so that they all set themselves in the direction of the force. On this supposition the relation between B and H, in intense fields, becomes:

$$B = H + 4\pi I,$$

where I is the sum of the magnetic moments of the molecular magnets contained in unit volume of the material, and certain experiments of Ewing, Low, and Du Bois show that in iron, nickel, cobalt, and some alloys, B does actually exceed H by nearly a constant quantity when H lies between 2000 and 25,000 c. g. s. units. It will be clear that an assumption that the quantity $4\pi I$ in the above expression is a constant for high value of H involves the second assumption that the moment of individual molecular magnets is not affected by the external magnetic forces to which they are subjected, and while the experiments of Ewing, Low and Du Bois do not establish the constancy of this quantity, they at least give strong grounds for supposing that in certain materials the mutual interactions between the molecules are almost completely overpowered by a magnetizing force greater than 2000 c. g. s. units.

If this assumption is correct, the saturation value of $4\pi I$,—i.e., the constant quantity by which B exceeds H in fields above a certain inensity,—is established as a definite measurable physical constant for any magnetic material. This quantity may conveniently be referred to as the specific magnetism.

The experiments of Sir Robert Hadfield and Professor Hopkinson were carried out on a series of alloys of iron with carbon and other materials with the idea that not only might some deductions be drawn as to the magnetic properties of the materials, but also as to their constitution. The great advantage of the magnetic examination of such materials in intense fields lies in the fact that the saturation value of $4\pi I$ in a material consisting of a mixture of substances is dependent only on the relative proportions and the magnetic properties of the various substances separately, and not on their arrangement in the mass. Most steels consist of such a mixture of substances, and any examination of their magnetic properties in fields of ordinary intensity is so complicated by molecular interactions determined by the microstructure that it is hopeless to look for any simple relation between their magnetic properties and their composition. In intense fields, however, troubles disappear owing to the swamping of the molecular interactions, so that the magnetic properties of an alloy become a measure of its composition. The many experiments which have been so far carried out definitely establish a saturation intensity of magnetization for all the alloys examined, and at the same time show that the method is capable of being used in an examination of the actual physical constitution of alloys, although the work has not yet been carried beyond a preliminary stage.

The measurements were carried out on small testpieces $\frac{1}{8}$ in. in diameter, and in most cases $\frac{1}{4}$ in. long, which were placed between the poles of an electro-magnet and surrounded by a small test-coil connected to a ballistic galvanometer. The tests were carried out by reversing the current passing through the coils of the electro-magnet and observing the galvanometer deflection. The electro-magnet had conical or flat pole-faces depending on the field intensity which was being used, and various corrections were made to allow for the distortion of the field due to the presence of the testpiece. Field intensities up to 25,000 c. g. s. units were employed. In most cases saturation was reached in a field of 5000 units, but with a few materials there was a small increase between 5000 and 25,000 units. In all cases, however, the form of the curve connecting I and H left no doubt as to the existence of a saturation value of $4\pi I$; while in addition all the materials behaved as though they consisted of a mixture of magnetic substances with non-magnetic substances having a permeability of about unity. None of the alloys which were examined had a higher specific magnetism than pure iron. These facts are, of course, in accordance with the theory that in intense fields the molecular inter-

actions are entirely swamped, so that the value of the specific magnetism becomes a measure of the amout of magnetic material present in a body, and so of its constitution.

Measurements which were carried out on a specimen of annealed iron-carbon steel, in which other elements were present in but small proportions, showed that the specific magnetism of the specimen was less than that of pure iron by a percentage equal to six times the percentage of carbon present. If this alloy be regarded as a mixture of pure iron with carbide of iron Fe_3C, the proportion of carbide of iron would be 15.5 times the proportion of carbon, from which it follows, assuming that the two constituents are mechanically mixed, that the specific magnetism of carbide of iron is about two-thirds that of pure iron. A series of measurements were carried out with iron-carbon steels, which showed that when less than $\frac{1}{2}$ per cent. of other substances were present, the effect of adding carbon was to reduce the magnetism by an amount proportional to the amount of carbon, the reduction being about six times the amount of carbon. Impurities present tended to mask the effect of the carbon to some extent, but a diagrammatic plotting of the reduction of specific magnetism against the proportion of carbon gave a straight-line curve with sufficient accuracy to suggest that the method might be used for determining the amount of combined carbon in a steel. Some of these iron-carbon steels were also examined after quenching from a high temperature. In general the effect of this was to reduce the specific magnetism but the results obtained were somewhat inconsistent. For instance, three samples were cut from a lump of white Swedish iron which had been quenched when molten, and the specific magnetism in percentages of that of pure iron proved to be, for the three specimens, 58.5, 64, and 72. These indefinite results must, of course, be attributed to the somewhat uncertain character of the quenching process. A somewhat similar result to the above was found with two samples of a silicon-manganese steel, which were quenched from 1200°; in one case the specific magnetism was found to be 62 per cent. of that of pure iron, and in the other only 20 per cent. Three samples of the same material, however, quenched from 1050° had a mean specific magnetism of 87.8 per cent. that of pure iron, which differs but little from 88.6 per cent., which is the mean of two annealed specimens. It is suggested that the difference in the two pieces quenched from 1200° may be explained by difference in the rate of cooling, as one piece was larger than the other, while the results obtained with the samples quenched from 1050° may have been due to the formation of cementite, which would occur at about 1100° as it is possible that the effect of quenching may depend upon whether free cementite is present or not.

The total number of samples of various alloys which were examined was very large, and it is not possible to give the results

in any detail in this article. In general, it may be said, however, that silicon appeared to act as an inactive diluent, and that some of the silicon-iron alloys were very soft magnetically, suggesting that silicon has the effect of reducing the interaction of the iron molecules. In some few cases silicon appeared to neutralize the effect of the carbon to some extent. Aluminum acted generally in a somewhat similar manner to silicon. The results obtained with iron-manganese alloys were very variable, and the authors were unable to find any simple relations between the proportion of manganese and the corresponding reduction in specific magnetism; they suggest that the effect of manganese may have been masked by that of some unknown variable, such as the temperatures to which the alloys may have been subjected during rolling or forging. The effect of heat-treatment on these alloys was exhibited by a sample containing 1.3 per cent. of carbon and 8.7 per cent. of manganese. As forged, this material had a value of B equal to 747 in a field of 240, while when annealed it had a value of 1985 in the same field, and when oil-hardened a value of 733. This shows that the cooling in air after forging had all the effects of oil-cooling, and suggests that such cooling, which, in the case of an iron-carbon alloy, has not much effect, is rapid enough in the case of an iron-manganese alloy to give the effect of quenching. The results obtained with iron-nickel alloys were also inconclusive, and they are now undergoing further investigation. This series, however, contained with iron-nickel alloys were also inconclusive, and they are greater than that of its elements taken separately. This was an alloy containing 11.4 per cent. of nickel, whose specific magnetism when saturated was 96 per cent. of that of pure iron. The alloy contained 87 per cent. of iron, and as the 11.4 per cent. of nickel is magnetically equivalent to about 3.5 per cent. of pure iron, the total specific magnetism of the constituents taken separately is only 90.5 per cent. as compared with the 96 per cent. given in the alloy. It will be clear that the investigation recorded in the paper is likely to be of much importance, and that although the results obtained so far rather indicate a new road for research than travel very far along it, the work forms an important contribution to the methods of research into the constitution of the iron alloys.

The Density of Radium Emanation. SIR WM. RAMSAY and R. W. GRAY. (*Comptes rendus*, cli, 126.)—The density of the radium emanation was approximately determined by weighing, on a specially designed micro-balance, a known volume of emanation calculated on the assumption that the amount of emanation in radioactive equilibrium with 1 Gm. of radium is 0.601 cubic mm. The mean value of five determinations gave 220 as the molecular weight: the highest was 227 and the lowest 216. The name of " Niton " is proposed for radium emanation.

Diffusion Phenomena of the Alums. C. L. PARSONS and W. W. EVANS. (*J. Amer. Chem. Soc.*, xxxii, 1378.)—When dissolved in water alums decompose into simple sulphates which may be separated by diffusion. The alums examined were ammonium-chromium, potassium-chromium, ammonium-aluminum, potassium-aluminum and ammonium-ferric alums. It was found that the separation by diffusion was more readily effected with the chrome alums than with the aluminum alums.

A New Remedy for Burns. ANON. (*La Nature*, No. 1959, 13.)—This is simply a lukewarm yeast poultice; either the dry yeast of grain or the wet yeast of breweries. The poultice is applied to the burns as quickly as possible. The pain subsides quickly and healing is remarkably hastened. From the recent work of Fernbach it appears that the cellules of the yeast can absorb the bacterial poisons.

Deciphering Writing on Burned Paper. ANON. (*La Nature*, No. 1759, 13.)—This is a most interesting problem either from the legal point of view, or from that of examining historical or other documents. The ashes of a large number of papers have been studied, and the traces left by the ashes of different inks or pencils. All trace of writing made with an ink composed of organic coloring matter or of lamp-black, *e.g.*, blue, red, violet and printing inks disappears on incineration; while inks composed from an iron salt, such as are generally used in Europe, leave a red-brown residue of ferric oxide. In this case the traces of writing become quite visible in the ashes of completely burned paper, and interesting documents, which were accidentally, or intentionally consumed, have been thus reproduced.

The Daily Motion of the Top of the Eiffel Tower. R. M. BOURGEOIS. (*Moniteur scientifique*, xxiv, 764.)—The Eiffel tower moves perceptibly daily under the influence of the heat of the sun. The extreme daily variation of the tip of the lightning conductor is the same as in 1896, and varies according to the atmospheric conditions from 3 to 17 cm. The mean position of the lightning conductor with reference to a fixed point has not sensibly varied from 1896 to 1908. The change of direction of the motion with the seasons confirms the fact, that the daily displacement of the top of the tower is certainly due to the sun.

Dielectric Behavior of Melted Vaseline. L. MALCLÈS. (*Comptes rendus*, cli, 63.)—A condenser made with a cell of insulating material, in which the vaseline is placed, is connected with one pair of quadrants of an electrometer and balanced against an adjustable condenser. The condensers are charged and a balance adjusted, and any after-effect is shown by a deflection of the electro-

meter needle. With vaseline in the ordinary semi-fluid state there is no after-effect, indicating that in this state vaseline is a perfect insulator, with a dielectric constant 1.97. When the cell between the condensers is filled with liquid vaseline and the vaseline allowed to cool and solidify, anamolous effects are observed, which the author explains by assuming that vaseline acts as a medium containing free ions, whose mobility is zero in the semi-fluid state but observable in the liquid state.

The Law of the Variation of the Coefficient of Specific Magnetization of the Elements by Heat. KOTARO HONDA. (*Mon. Sci.*, xxiv, 767.)—The effect of a rise in temperature on the coefficient of magnetization of an element is equal to that of a small increase in the atomic weight of that element. This law, to which no serious exception is found, is certainly very important to the electronic chemistry of matter.

John Mayow and His Theories. MAX SPETER. (*Chem. Ztg.*, xxxiv, 946.)—This is a history of the views and experiments of John Mayow, who lived from 1645 to 1679, whose theory of respiration and combustion first developed the correct view of the matter, thus forestalling Lavoisier by more than a century. The evidence goes to show that Lavoisier was well acquainted with, and borrowed from, Mayow's work, although he does not refer to him.

Preparation of Titanium. M. A. HUNTER. (*Amer. Chem. Soc. Jour.*, xxxii, 330.)—Pure titanium cannot be obtained by the methods described by Berzelius, or Wöhler and Deville, or by Moissan. A yield of pure Ti, amounting to about 90 per cent. of the theoretical, was obtained by the reduction of titanium tetrachloride with sodium in an air-tight steel cylinder. The metal titanium resembles polished steel. When cold it is hard and brittle, but is very malleable at a low red heat. Its specific gravity is 4.50, and its melting point lies between 1800° C. and 1850° C.

Improved German Silver Alloy. W. R. BARCLAY and J. RODGERS. (*Soc. Chem. Eng. J.*, xxix, 161.)—The addition of a small percentage of cadmium to low-grade German silver, increases the hardness and general working qualities and color to that of a first or second grade alloy containing 22 to 30 per cent. of nickel. An example of modified German silver is copper 57 per cent., nickel 12.5, zinc 28.5, and cadmium 2 per cent.

French Service Powder. G. GEUMANN. (*Zeit. des Schiess- und Sprengstoffw.*, v, 449.)—From 1866 to 1884 considerable alterations were made in the composition and form of black powder and also in the nature of the charcoal used. In 1884 Vieille introduced a smokeless powder, known as "B" powder which with

various modifications is still retained as the service powder. Originally it consisted of insoluble nitrocellulose 68.21 per cent., soluble nitrocellulose 29.79 per cent. and paraffin 2.00 per cent. This was gelatinized with ethyl acetate and made in the flake form. Later this was modified and the composition became insoluble nitrocellulose 29.13 per cent., soluble nitrocellulose 41.31 per cent., $BaNO_3$ 19.00 per cent. KNO_3 8.00 per cent. and Na_2CO_3 2.00 per cent. This was gelatinized first with ether alcohol and later with methyl alcohol. Recently a pure nitrocellulose powder, containing certain stabilizers has been adopted.

Use of Nickel-Steel in Bridge Building. F. BOHNG. (*Chem. Zeit,* xxxiv, 1359.)—Experiments in the use of special steels for bridge construction date back to 1903 in America. In Germany the use of nickel-steel for bridges was first proposed in 1908 and was favorably considered by the authorities. The first work undertaken was a small railway bridge at Oberhausen, of 31.5 metres length between supports. Nickel-steel was also used in the construction of a suspension ferry over the harbor entrance of the Imperial Dockyard at Kiel, and of a covered foot-bridge over the Rhine-Herne Canal near Oberhausen. The steel contained 2 to 2½ per cent. of nickel with a strength of 56—65 kilos per square mm. In some cases nickel may be replaced by the slightly cheaper chromium.

Preliminary Estimate of Production of Portland Cement in 1910.—The production of Portland cement made a new high record in the year 1910. From statistics and estimates received by the United States Geological Survey from about 20 per cent. of the companies manufacturing Portland cement, representing nearly half of the entire output of the country, it is estimated by E. F. Burchard, of the Survey, that the quantity of Portland cement manufactured in the United States in 1910 was between 73,500,000 and 75,000,000 barrels, as compared with 63,508,471 barrels produced in 1909—an increase of 10,000,000 to 12,500,000 barrels, or 15 to 20 per cent. The figures at hand are derived from all parts of the United States, and are therefore considered to be representative of the country at large rather than of any single section or district.

Although the average values for 1910 appear, from returns received thus far, to have been slightly higher than in 1909, prices were far from satisfactory, especially to the large manufacturers in the Lehigh Valley district and in certain of the Eastern States. The year 1911 opens with prices cut 5 to 10 cents a barrel lower than those prevailing in 1910. The construction of several new plants has been pushed during the year, and several plants that were under construction in 1909 became producers in 1910, so that the kiln capacity remains far in advance of the demand.

Commerce of the United States. (*Amer. Mach.,* xxxiii, 714.)—For the first time in the history of our commerce, manufactures now form more than one-half of the total exports. In the 8 months ending with August the figures of the Bureau of Statistics of the Department of Commerce and Labor show that out of a total exportation of 1027 million dollars, manufactures amounted to 542¾ millions or 52.8 per cent. of the whole. Steel and iron are conspicuous in the list of manufactured products which account for the increase.

One Reason Why Steel is Not Uniform. R. E. MARKS. (*Amer. Mach.,* xxxiii, 723.)—He describes somewhat humorously a visit to a steel plant where the heat was determined by the sight-judgment of the " head looker " without any pyrometers or other instruments to determine the temperature. They did not know " what kind of an animal a pyrometer was, but knew there were none round there."

A Laboratory Furnace for Very High Temperatures. D. F. CALHANE. (*Met. and Chem. Eng.,* viii, 581.)—This convenient and inexpensive furnace, of the electrical resistance type, consists of a small, vertical fire-clay muffle, standing within an enclosure formed of four firebricks, the space between the muffle and the bricks is filled with a mixture of Portland cement, magnesium oxide and asbestos. At the bottom of the muffle there is an alundum block on which rests a graphite crucible 2 inches high. The space between the crucible and the muffle is filled with carbon powder, which forms the resistance. A ring of carbon fits flush at the bottom of the muffle and a second ring is provided just above the top of the crucible. The current enters at the bottom, where it is evenly distributed by the ring and leaves at the top ring. To concentrate the heat on the walls of the crucible, an alundum insulating ring is placed at some distance between the graphite rings, practically dividing the mass of resistance carbon into two portions, causing the current to flow along the sides of the crucible. The crucible is lined with alundum to prevent the metals or alloys being contaminated with carbon. The furnace has a capacity of one kilowatt, weighs about 25 lbs., and is capable of heating 60 or 70 Gm. of metal up to 2500° C. The total cost should not exceed $5.00.

The Sun as a Source of Heat in Chemical Experiments. A. STOCK and H. HEYNEMANN. (*Ber. Deutsch. Chem. Gesell.,* xlii, 2863.)—If the substance to be treated is contained in an exhausted glass vessel, the heat can be concentrated on the substance itself, so that a very refractory container is not requisite. The apparatus employed is a plano-convex lens of 40 cm. diam. and 50 cm. focal length used to concentrate the sun's rays on

the substance, which was placed in a magnesia crucible. Pieces of copper and cast-iron were melted almost instantly, while crystallized silicon, M. Pt. 1450° C., was melted in a few seconds. A thermo-junction supported at the centre of the flask gave a reading of 1030° C. in vacuo; but only 675° C. when unexhausted.

Removal of Tin from Tin-plate. ANON. (*Brass World*, vi, 434.)—It is well known that a strong solution of sodium hydroxide (caustic soda) will dissolve metallic tin from tin-plate scrap, leaving the bare iron. The solution contains the tin as sodium stannate from which it can be recovered electrolytically. The difficulty in this process is that after a while the soda solution will not attack the tin. Heinrich Brandenburg overcomes this by constantly removing a portion of the solution by a pump and supplying fresh caustic soda in its place. It is stated that the solution will then attack the tin regularly and thus the difficulty is overcome and the process made continuous.

The Influence of Pure Science in Engineering. SIR J. J. THOMSON, F.R.S. (*Eng. Record*, lxii, 679.)—This is a Presidential address read before the Junior Institution of Engineers, and is worthy of perusal by engineers and by scientists. It shows that "the distinction between pure science and engineering is one, not of method, but of aim." Its perusal is strongly recommended.

The Heroult Patents. ANON. (*Iron Age*, lxxxvi, 1110.)— The United States Steel Corporation has acquired the rights for the United States in the Heroult process for electric steel making and refining. Two fifteen-ton Heroult furnaces have been operated for a year, one at the South Chicago works of the Illinois Steel Co., and the other at the South Works, Worcester, Mass., of the American Steel and Wire Co. At South Chicago several thousand tons of rails and a large tonnage of axles have been made of electric steel, the Heroult furnace operating as an adjunct of the Bessemer converter. At Worcester the Heroult furnace is used to refine open-hearth steel, an exceptionally high quality of steel being made from ordinary materials.

The Volatile Constituents of Coal. M. J. BURGESS and R. V. WHEELER. (*Proc. Chem. Soc.*, xxvi, 210.)—With all coals, whether bituminous, semi-bituminous or anthracite, there is a well defined decomposition point at a temperature between 700° C. and 800° C., which corresponds with a marked increase in the quantity of hydrogen evolved. With bituminous coals this increase of hydrogen evolved falls off at temperatures above 900° C., but with anthracite coal the evolution is maintained up to 1100° C. It is further shown that ethane, propane, butane, and probably higher members of the

paraffin series of hydrocarbons form a large percentage of the gases evolved at low temperatures, but that at above 700° C. the evolution of such hydrocarbons practically ceases. The idea is advanced that coal, of whatever geological age, contains a compound which decomposes at temperatures above 700° C. under atmospheric pressure, and yields hydrogen as its chief gaseous product. It seems probable that the same compound is responsible for the hydrocarbons of the paraffin series that make their appearance at low temperatures.

Preparation of Metallic Vanadium. W. PRANDTL and B. BLEYER. (*Ber.*, xliii, 2602.)—Vanadium pentoxide can be reduced by the thermite reaction by mixtures either of aluminum and calcium or aluminum and fluorspar in magnesia crucibles, and by aluminum alone on a fluorspar hearth. Whichever method is used, however, the resulting vanadium regulus never contains more than 95 per cent. of vanadium. The deficit does not consist of impurities introduced by the calcium, but is practically all oxygen, as only traces of aluminum, silicon, and iron could be detected. Probably a lower oxide of vanadium and metallic vanadium unite to form an alloy which withstands further reduction.

Axin, a Mexican Lac. H. BOCQUILLON. (*J. Pharm. Chim.*, ii, 406.)—Axin is a waxy secretion of a Mexican rhyncotrous insect. When fresh it has the consistency of butter, a yellow color and an odor of rancid fat. It melts at 38° C. and is soluble in hot alcohol and in ether. When exposed to the air it rapidly absorbs oxygen and becomes dark brown, hard and insoluble in the above solvents. It is readily saponified. Hoeffer has extracted from it a definite substance " axinin," which yields axinic acid and glycerol. In its properties of darkening and hardening on exposure to air, axin closely resembles Japan lac. It forms an excellent lacquer for wood and metals, and is used by the natives as a varnish for pottery.

Petroleum in the Argentine. W. MECKLENBURG. (*Chem. Zeit.*, xxxiv, 1150.)—Petroleum has as yet only been found in the Argentine in the provinces to the east of the Andes, notably at Jujug, Salta, Mendoza, Los Buitres, Neuguén, and Chubut, but it probably occurs in many other places. Argentine oils are viscous and of dark color, that from Chubut being quite black. The Yacuiva oils have the best appearance and those of Salta come next. They are reddish brown and have a strong greenish fluorescence. The oils of Salta, Jujug, and San Rafael (Mendoza) have an odor of lamp oil, while the oils of Cacheuta and Comodoro Rivadavia, from the deep strata, have an odor of benzine. The Argentine petroleums resemble Baka oils much more closely than Pennsylvania oils.

Polychrome Screens for Color Photography. L. GIMPEL. (*French Pat.*, 414,953, 1909.)—A screen composed of parallel lines is photographed on an ordinary photographic plate, and the developed and fixed image is toned in a primary color (*e.g.*, red) to give an image of as fine a grain and as transparent as possible. The film is now coated with a sensitive emulsion, and the screen is photographed again on this, but with the lines perpendicular to those of the first image; after development and fixing, the second image is toned in a second primary color (*e.g.*, blue) and the plate is again coated with emulsion, and exposed to the light through the crossed screen already formed, so that only the portions not colored are affected; it is finally developed, fixed, and the image of small squares toned to the third primary color (yellow).

Metallic Titanium. L. WEISS and H. KAISER. (*Zeit. Anorg., Chem.*, lxi, 345.)—The paper describes the methods of preparation and analysis of amorphous and cast titanium and of titanium "aluminides." A product prepared by fusing the amorphous metal contained 97.41 per cent. titanium and its specific gravity was 5.174 at 19° to 20° C., mean specific heat 0.1418 and heat of combustion 24.4 calories per equivalent. It melts at 2200° to 2400° C.

Preventable Blast-Furnace Accidents. R. H. SWEETSER. (*Iron Age*, lxxxvi, 1022.)—A valuable and useful paper on the prevention of such accidents. Mr. Sweetser points out that accidents can arise from slips and from the different kinds of furnace gas, *e.g.*, the normal gas and the blowing in gas, from explosions in the cold blast pipe, from slips, break outs, and blowing outs. This paper will doubtless be very interesting to blast-furnace men.

Effect of Heat on Cast-Iron. (*Amer. Mach.*, xxxiii, 720.) —Heating cast-iron to a dull red heat and allowing it to cool, repeated 30 or 40 times, makes it porous. Cast-iron plates so treated, after being planed down to a $\frac{1}{4}$-inch thickness, will absorb a few drops of oil placed on the top, which will pass through the iron to the lower side of the plate in less than 5 minutes.

Specification for the Manufacture and Testing of Retort Material. (*Jour. of Soc. Chem. Ind.*, xxx, 28.) — A joint subcommittee formed of five representatives elected by the Retort and five of the Refractory Materials Committee of the Institution of Gas Engineers, with the assistance of J. W. Mellor, of the Staffordshire County Pottery Laboratory, has drawn up a specification for this purpose. The leading points covered are: Constituents, Chemical Analysis, Refractoriness, Surfaces and Texture, Contraction, Inspection and Testing. To those interested this will be found a valuable paper.

Brass-Melting Furnaces. W. M. CORSE. (*Iron Age*, lxxxvii, 82.)—The new types of brass furnaces introduced during the last 10 years have led to a thorough investigation of the causes of brass founders' troubles. It was a revelation to many that zinc could be volatilized to the extent of 45 per cent. during the process of melting. These furnaces may be divided into five classes.

1. Stationary crucible furnaces, coke or coal fired, using natural or forced draft.
2. Stationary crucible furnaces, oil fired.
3. Tilting crucible coke furnaces.
4. Tilting crucible oil furnaces.
5. Tilting open-flame oil furnaces, without crucibles.

The quality of the metal from class 1, with natural draft is excellent, provided the draft equals 2″ or 3″ water suction. Poor draught causes inefficient working.

In class 2, the quality of the metal depends on the design of the furnace and on the air pressure. Generally the lower the air pressure, the better the metal.

In class 3, the melt is much faster, with the disadvantage of double pouring.

In class 4, there is the same efficiency as in class 2, with the double pouring factor.

In class 5, there is the same efficiency as in the other oil furnaces, also with the double pouring factor.

Pilbarite from the Pilbara Goldfields. E. SIMPSON. (*Chem. News*, cii, 283.)—Pilbarite is a canary yellow, brittle, earthy, amorphous mineral of 2.5 to 3 hardness, and has a specific gravity of 4.4 to 4.7. It is found in small quantities at Wodgina, Pilbara Goldfields. The mineral is essentially a hydrated silicate of lead, uranium and thorium. It is readily decomposed by mineral acids and is strongly radio-active.

Direct Reduction of Iron Ores in the Electric Furnace. M. G. ARNOU. (*Rev. de Metall.*, vii, 1190.)—Hæmetite, magnetite, and clay-ironstone were reduced with either wood charcoal, coke, or anthracite in an electric furnace capable of producing 15 tons of metal. Finely powdered mineral was reduced as easily as an agglomerate of briquettes. The analysis of seven consecutive castings closely approximate to 0.08 per cent. carbon, 0.10 manganese, 0.02 silicon, 0.02 sulphur, with traces of phosphorus. It is stated that the metal, so far as tested, shows a perfect similarity to Swedish iron.

New Compounds of Nitrogen and Hydrogen with Lithium. F. W. DAFERT AND R. MIKLAUZ. (*Monats Chem.*, xxi, 981.)— At the ordinary temperature metallic lithium in a current of pure dry nitrogen is gradually but completely converted into lithium

nitride, Li_3N. At 400° C. the reaction is very rapid, but as the substance attacks the container the final product is very impure. The nitride heated to 220°–250° C. in a stream of hydrogen absorbs the gas forming tri-lithium ammonium, Li_3NH_4. This when heated to 340° C. loses hydrogen, and reabsorbs it on cooling, but when heated to 480° C. the loss of gas is permanent, and tri-lithium amide, Li_3NH_2, is formed. Heated to 600°–800° C. in a steam of hydrogen it forms lithium hydride. All of these compounds are decomposed by water with evolution of ammonia.

The Oxides Which Color the Oriental Sapphire. A. VERNEUIL. (*Comptes rend.,* cli, 1053.)—Titanium has not been hitherto detected in the clear sapphire, and its color is due to iron oxide. The identity of the color of the synthetic product with that of the natural stone indicates that titanic acid or oxide produces the coloration. The analysis of Australian, Burmese and Montana sapphires shows they contain iron oxide, and a titanium oxide equivalent to 0.031–0.058 per cent. of titanic acid. The conclusion is drawn that the Oriental sapphire owes its fine blue color to iron oxide and titanium oxide.

Reaction in the Electric Arc. PAUL SABATIER. (*Comptes rendus,* cli, 1328.)—M. Salmon has described an arrangement "for passing the electric spark between two electrodes each pierced by an axial channel, so that gas passes through one channel and the products of the reaction escape by the other one." One result obtained in this way was the combination of carbon and nitrogen to form cyanogen.

For ten years I have used a very simple analogous arrangement, consisting of two hollow carbons. They only differ from M. Salmon's arrangement in that the quartz tube envelope is replaced by a cylindrical glass lamp-chimney protected on the interior from the radiation of the arc by a fine metallic lining. In this apparatus the synthesis of acetylene in a current of hydrogen, and of ammonium cyanide in ammonia gas, can be effected. But it should be noted that, with a current of 90 volts and 15 amperes, absolutely dry nitrogen gives no appreciable cyanogen, while hydrocyanic acid is plainly formed when the nitrogen is a little damp, or mixed with hydrogen or a hydrocarbon.

The Carborundum File. ANON. (*Eng. Mag.,* xl, 3.)—Carborundum is the hardest and sharpest of all abrasive materials. Each grain is as hard and as sharp as a diamond, and cuts fast and clean, does not wear smooth nor does the file fill or glaze. The carborundum file will remove material that the steel file cannot touch. One such file it is stated, will outlast twenty steel files, and will cut metals which a steel file cannot touch.

The Outerbridge Silicon Alloys. (*Iron Age*, lxxxvii, 44.)—This alloy patened by Mr. A. E. Outerbridge of Philadelphia makes gray-iron castings stronger, cleaner and more homogeneous; it reduces shrinkage, cracking and blow holes and increases ductility. It controls the character of the iron drawn from the cupola as a governor controls the revolution of an engine, and enables the grade of iron in individual ladles to be varied to suit special castings. It drives the dirt and slag to the top where it can be skimmed off. No expert or chemist is required to direct its use, as it is only necessary to drop a small quantity of the finely ground alloy on the bottom of the ladle before tapping.

Energy from Niagara. (*Eng. and Mining Jour.*, xc, 1119.)—The *Electrical World* states that the energy from Niagara Falls, including operation on both sides of the Falls, is used at the rate of 126,000 h. p. for electro-chemical process; 56,200 h. p. for railway service; 36,400 h. p. for lighting, and 54,540 h. p. for various industrial services; the total being 273,140 h. p. Since the water of Niagara Falls represents probably 5,000,000 h. p. it would seem that only about 5.5 per cent. of the available power is being utilized at present.

Low Temperatures in the Leather Industry. W. EITNER. Zeit. Angew. Chem., xxiii, 2268.)—Although temperatures below zero are harmful, the cooling of hides before preservation with salt and storage of the salted hides at temperatures below 10° C. is advantageous. Unhairing by the sweating process is also best regulated by means of artificial cooling.

Matches in China. (*La Mercure Scientifique,* lxxiv, 4.)—The Japanese have developed the extensive manufacture of matches in China. There are factories at Tientsin, Pekin, Hangkow, Shanghai, and other places. The viceroys do not allow the erection of several factories in the same town, so that each factory has a kind of local monopoly. The factory at Hangkow employs 3600 hands, and produces 50 or 60 tons daily. If this development increases the Japanese manufacturers will be unable to stand the competition.

The Efflorescence of Bricks. JULES GARÇON. (*Bull. Soc. D'Encour.,* cxiv, 455.)—The color of the efflorescence of bricks is generally white, but sometimes yellow or green, and is usually seen on red bricks. In time it spreads over a whole building and gives it a dusty appearance. It is formed when the brick contains soluble salts, generally sulphates; but sometimes chlorides. When the bricks absorb water it evaporates on the surface leaving the salts. These soluble salts may have been in the clay, in the water used to wet the clay or in the mortar. Sometimes these salts are

formed in firing the brick by the sulphur dioxide gas from sulphur-
ous coal. To avoid this, if the clay contains the salts it should
be well washed, or be left exposed to the rain for 6 months or a
year. If the clay contains pyrites, 4½ pounds of barium chloride
or 22 pounds of barium carbonate should be added to the water
for each ton of clay.

The Influence of the Magnetic Field on Spectral Rays. G.
A. HEMSALECH. (*Moniteur Scientifique,* lxxiv, 57.)—The influ-
ence of the magnetic field on the duration of the spectral rays
emitted by luminous vapors in the electric spark is that the duration
of almost all the rays of iron is diminished and the intensity of the
action upon the different rays is selective. Almost all rays decrease
in intensity, except in the immediate vicinity of the electrode, where
they are all reinforced by secondary reactions. (1) *The general
effect,* which is independent of the orientation of the discharge with
respect to the lines of force of the magnetic field, results in the
decrease of the duration as well as of the luminous intensity of
the rays emitted by the metallic vapor. (2) *The longitudinal effect*
produces a prolongation of the duration of the metallic rays and
an increase of their brightness as well as of the brightness of the
air. This action is only apparent when the spark flashes parallel
to the lines of force. (3) *The transverse effect* is only obtained
with very slow discharges (self-induction in the discharge circuit
of the condenser) when the spark flashes perpendicularly to the
lines of force. This effect is shown by a prolongation of the dura-
tion of certain rays, and is due to the displacement experienced by
the oscillation which carries the current of the discharge under
the influence of the field. Its action is selective.

Nickel Anodes. ANON. (*Brass World,* vi, 433.)—Nickel
anodes that have been sand-blasted work better than those left
as they come from the sand mold.

Electro-deposited Nickel. ANON. (*Brass World,* vi, 437.)
—By heating electro-deposited nickel that is hard and brittle in
an atmosphere of hydrogen to a red heat, it becomes soft and
ductile.

SOME CAUSES OF VARIATION IN THE POLARIZATION OF SKY LIGHT.*

BY

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INTRODUCTION.—Since the discovery of the polarization of sky light by Arago more than a century ago the phenomenon has been studied by many eminent investigators; but, while its general features have been satisfactorily accounted for, certain variations that appear to be connected with atmospheric conditions still remain to be examined and explained. In the present paper the general features of sky polarization will be considered first, together with a brief reference to some of the theories that have been advanced to account for them. There will then follow a more detailed account of certain variations with location and with atmospheric conditions, which have been made the subject of extended observation by the writer.

GENERAL FEATURES.—If we examine with a polariscope the light from a cloudless sky when the sun is on the horizon, we shall find that from 70 to 80 per cent. of the light from the zenith is plane polarized, and that the zenith is the point of maximum polarization. Furthermore, a maximum percentage of polarized light is found in the plane at right angles to the direction of the incident solar rays, although the percentage decreases somewhat

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[NOTE.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the Journal.]

with angular distance from the zenith. At the time of the equinoxes this plane cuts the horizon at the north and the south points. Along the horizon, therefore, both east and west from these points, the polarization diminishes. It also diminishes as we pass from the zenith towards the east or west; and reaches a minimum, in this case zero, at points from 15° to 25° above the anti-solar point and the sun, and which are called from their discoverers the neutral points of Arago and Babinet, respectively.

Generally speaking, the plane of polarization is the plane containing the sun, the point from which light is observed, and the eye of the observer. For the zenith this coincides with the vertical plane of the incident solar rays; for a point on the horizon it is a horizontal plane; and for an intermediate point, a more or less inclined plane. In the vicinity of the neutral points the plane of polarization is more nearly horizontal than would be the case if the above rule applied, except that directly above them it is vertical. At all points directly below them it is horizontal.

As the sun increases its angular distance above the horizon one continues to find the point of maximum polarization about 90° from the sun and in its vertical. The maximum percentage of polarization is still found in the plane at right angles to the incident solar rays; and one continues to find points of zero polarization above the sun and the anti-solar point, although the distance of the former from the sun gradually diminishes. About the time that Arago's neutral point disappears below the horizon Brewster's neutral point makes its appearance above the horizon underneath the sun. Other neutral points have also been observed at different times.

The principal features of sky polarization are, therefore, a point of maximum polarization about 90° from the sun and in its vertical, a plane of maximum polarization at right angles to the incident solar rays, and points of neutral polarization at about 15° to 25° above and below the sun, and about the same distance above the anti-solar point. The plane of polarization is, in general, the plane containing the sun, the point observed, and the eye of the observer; but this rule does not apply to the region immediately about the neutral points. It will also be useful to remember that the light vibrations occur in a plane which contains the point observed and the eye of the observer, and which is at right angles to the plane of polarization.

EXPLANATION OF SKY POLARIZATION.

EFFECT OF PRIMARY SCATTERING.—Between the years 1871 and 1899 Rayleigh and others showed how a medium made turbid by the presence of particles whose diameters are small in comparison with the wave-length of light would scatter the light, the variation in the intensity of the scattering with direction being expressed by $1 + cos^2\beta$, where β is the angular departure from the line of incidence. According to this law the scattering would be twice as intense in the line of incidence as at 90° from it. Furthermore, it was shown that light scattered from an unpolarized beam would be completely polarized in a plane at right angles to the incident beam. That is to say at right angles to incidence all the light vibrations would take place in this one plane. In the direction of the sun and of the anti-solar point, respectively, the light would be unpolarized. Between these points and the plane of maximum polarization the fraction of the light polarized would be expressed by $\frac{sin^2\beta}{1+cos^2\beta}$, or the percentage of the light polarized would vary between 0 and 100.

EFFECT OF SECONDARY SCATTERING.—In 1888 Soret [1] showed that if the small diffusing particles were distributed uniformly throughout a hemisphere the effect of secondary scattering would be identical to the effect produced by a beam of natural light coming directly from the sun, plus the action of a beam of much less intensity contained and polarized in a plane perpendicular to the direction of the sun. The vibrations in this beam are therefore at right angles to the vibrations in the primary scattered light, and this beam is said to be negatively polarized in distinction from the prevailing, or positive polarization. The effect of this negatively polarized beam will be everywhere ·to neutralize a part of the positive polarization, thus giving only partial instead of total polarization 90° from the sun. In the directions toward and from the sun, however, the light would still be unpolarized.

But the diffusing particles, instead of being distributed uniformly throughout a hemisphere, are actually contained in a relatively small segment of a sphere, and there are many more particles, both of gas and of foreign substances, in the lower layers than in the upper. As an approximation to the actual distribution, Soret supposed a horizontal ring of diffusing particles

to superpose its effect upon that of the hemisphere. In the light scattered by this ring horizontal polarization would predominate; and in the direction of the sun and of the anti-solar point the superposition of this component upon the components due to primary scattering and the secondary scattering by the assumed hemisphere, would result in horizontally polarized light. As we proceed towards the zenith, however, we soon reach points where the vertically polarized light just neutralizes the horizontally polarized, giving us the so-called neutral points.

DIFFUSION BY LARGE PARTICLES.—Wiener [2] has shown that the presence of water drops would have little effect upon the polarization 90° from the sun; that ice crystals would appreciably diminish the polarization in that direction; and that, within limits, the presence of any particles whose diameters are large in comparison with the wave-length of light would greatly increase the sky illumination and the proportion of natural light in the vicinity of the sun.

REFLECTION FROM THE SURFACE OF THE EARTH.—My own observations, confirming those made by others, show that when snow covers the ground the percentage of sky polarization at the point of maximum may be diminished from 70 per cent. to 50 per cent., which corresponds to an increase in the ratio of the unpolarized to the polarized light of from 0.43 to 1.00. It is therefore evident that reflection from the surface of the earth increases the proportion of natural light. Reflection from large particles suspended in the atmosphere would also produce this same effect.

CAUSES OF VARIATION IN SKY POLARIZATION.—It therefore appears that an increase in the number of the diffusing particles, large or small, in the lower layers of the atmosphere, and, likewise, that increased reflection from the surface of the earth, must produce a diminution in the positive polarization of sky light, and at the same time increase the distance of the neutral points of Arago and Babinet from the anti-solar point and the sun, respectively.

PERIODIC VARIATIONS.

For many years Jensen [3] has measured the percentage of polarization at the zenith at different hours of the day. After correcting his readings for varying zenith distance of the sun, he finds that the minimum polarization occurs at about the time

of maximum temperature, which is also the time of maximum convection.

Rubenson [4] found the polarization at the point of maximum to be less in summer than in winter, a fact that may also be partly attributed to convection.

Busch [5] has found the distances of the neutral points of Arago and Babinet from the anti-solar point and the sun, respectively, to vary greatly from year to year,—in the case of the latter from an average of 15.4° in 1890 to an average of 30.8° in 1903. Reference may also be made to my own observations,[6] which show that the polarization at the point of maximum in the year 1903 averaged 10 per cent. less than the average for the years 1903 to 1910, inclusive. The year 1903 followed violent volcanic eruptions in the West Indies and Central America. Although this was not a year of maximum sun spots, Jensen [7] points out an apparent connection between the years with a maximum of sun spots and the years when the neutral points are at a maximum distance from the sun and the anti-solar point.

NON-PERIODIC VARIATIONS.

EFFECT OF WATER VAPOR.—Some observations by Crova and Houdaille [8] in 1888 indicate a connection between atmospheric transmission of solar radiation and sky polarization. During the past five years I have made a great many observations that clearly show such a connection. They also show a relation between sky polarization and local conditions, such as character of the soil, convection, etc. In order that these various relations may be more easily understood, the observations are summarized in Table I, where P_2 indicates the percentage of polarization of sky light at the point of maximum, e the vapor pressure, and Q_2 the intensity of solar radiation on a surface normal to the sun's rays and at mean solar distance, expressed in gram-calories per minute per square centimetre. P_2, e and Q_2 were all three measured when the sun was 60° from the zenith. The significance of Q'_2 is given below.

The Washington observations cover the period from December, 1905, to May, 1910. Observations at other stations, including some at Madison, Wis., on the position of the neutral points, and which are given in Table III, were obtained in connection with field work during the summer and fall of 1910. All the data were obtained when the sky was practically cloudless.

TABLE I.—SUMMARY OF SOLAR RADIATION AND SKY POLARIZATION OBSERVATIONS WITH THE SUN 60° FROM THE ZENITH.

WASHINGTON, D. C.

No. of half-day series of observations	P_2 Per cent.	e Mm.	Q_2 Calories	Q'_2 Calories
GROUP 1				
10..	70.8	3.54	1.329	1.302
GROUP 2				
10..	68.2	1.93	1.314	1.269
9...	66.2	2.76	1.259	1.223
15..	62.4	2.39	1.238	1.198
4...	57.8	2.89	1.183	1.149
7...	51.9	3.95	1.057	1.034
Averages.................................	61.3	2.78	1.210	1.175
GROUP 3				
8...	67.7	4.47	1.271	1.254
7...	65.8	6.66	1.255	1.262
13..	63.1	6.07	1.223	1.224
5...	57.4	8.32	1.077	1.103
7...	53.2	9.69	1.002	1.043
Averages.................................	61.4	7.04	1.166	1.177
GROUP 4				
2...	43.0	7.63	0.884	0.902

SANTA FÉ, NEW MEX.

	P_2 Per cent.	e Mm.	Q_2 Calories	Q'_2 Calories
Sept. 20, A.M.............................	61.0	6.50	1.282	1.286
Sept. 19, A.M.............................	70.8	8.48	1.360	1.382
13, P.M..............................	70.0	7.87	1.390	1.407
18, A.M..............................	68.7	8.81	1.343	1.368
8, P.M..............................	67.8	8.48	1.334	1.356
9, A.M..............................	66.8	8.48	1.319	1.341
Averages.................................	68.8	8.42	1.349	1.371

FLAGSTAFF, ARIZ.

Dates	P_2 Per cent.	e Mm.	Q_2 Calories	Q'_2 Calories
Sept. 25, A.M.............................	70.6	5.16	1.420	1.412
27, A.M..............................	70.1	4.17	1.360	1.344
28, A.M..............................	69.8	3.40	1.440	1.417
30, P.M..............................	69.3	2.49	1.452	1.420
26, A.M..............................	68.1	4.95	1.397	1.388
28, P.M..............................	68.1	2.62	1.417	1.387
26, P.M..............................	66.5	3.99	1.359	1.341
Averages.................................	68.9	3.83	1.406	1.387

PHOENIX, ARIZ.

	P_2 Per cent.	e Mm.	Q_2 Calories	Q'_2 Calories
Oct. 5, A.M..............................	63.2	7.04	1.228	1.239
3, A.M..............................	62.8	8.13	1.291	1.314
5, P.M..............................	62.7	8.81	1.268	1.299
3, P.M..............................	62.0	8.81	1.319	1.350
7, A.M..............................	60.7	5.16	1.292	1.283
7, P.M..............................	59.6	4.17	1.337	1.317
6, P.M..............................	59.4	5.79	1.240	1.238
8, A.M.	59.4	4.37	1.274	1.256
6, A.M.	58.6	8.18	1.239	1.263
Averages.................................	60.9	6.72	1.276	1.284

The data for Washington have been arranged in four groups in such a way that the averages for groups 2 and 3 give nearly equal values for P_2, but values of e differing by 4.26 mm. The corresponding difference in the values of Q_2 is 0.044, indicating that an increase of 1 mm. in the value of e diminishes the value of Q_2 by 0.010. This is very closely in accord with the empirical equation of Abbot and Fowle,[9] namely, $F = 5.1 + 0.12\ E_0 m$, where F indicates the depetion of solar radiation intensity due to water vapor band absorption in the solar spectrum expressed as a percentage of the value of the solar constant. $E_0 = 2.3\ e$ is the vapor content of the atmosphere expressed in millimetres of depth of water, and m is the secant of the sun's zenith distance. When $m = 2$, a change of 1 mm. in e will produce a change of about 0.55 in F, which is equivalent to a change in the intensity of solar radiation of about 0.011 calories, or practically the same as found from the data in Table I.

We may therefore employ the equation

$$Q'_2 = Q_2 - 0.011\,(e' - e)$$

to adjust the values of Q_2 obtained with various values of e to values Q'_2, corresponding to any desired uniform value of $e = e'$. In Table I they have been adjusted to a value of $e' = 6.0$ mm. The resulting values of Q'_2 show very clearly that a relation exists between Q'_2 and P_2, but do not indicate a direct relation between the latter and e.

Similarly, the averages for Santa Fe, N. Mex., and Flagstaff, Ariz., if we omit the data for Santa Fe on September 20, give nearly equal values for P_2, but values of e differing by 4.59, and values of Q_2 differing by 0.057, indicating a diminution of 0.012 in Q_2 for an increase of 1.0 mm. in e. Santa Fe is about 7000 feet and Flagstaff about 6900 feet above sea level. At this elevation the investigations of Abbot and Fowle [10] indicate that an increase of 1.0 mm. in e should cause a diminution of only 0.009 in Q_2. However, after employing this latter value to obtain Q'_2 corresponding to $e' = 6.0$ mm., the data indicates that with a transparency of the atmosphere at these two stations such that their average values of Q'_2 differ by only about one per cent., the averages of sky polarization are in accord. Here again the effect of e upon the value of P_2 is not apparent.

After adjusting the values of Q_2 obtained at Phoenix, Ariz., to values of Q'_2 corresponding to $e' = 6.0$ mm., we may bring

together in Table II the average values for Flagstaff, Santa Fe, and Phoenix, and the averages for the best observations at Washington, which latter have been obtained from the data for group 1, the first ten series of group 2, and the first eight series of group 3. From this table it is evident that with a given transparency of the atmosphere after allowance has been made for band absorption by aqueous vapor, the percentage of polarization of sky light with the sun 60° from the zenith is greatest at Washington and least at Phoenix.

In Table III are given observed distances of the neutral points of Arago and Babinet from the anti-solar point and the sun, respectively, and the highest polarization that has been observed with the sun on the horizon. At Washington no observations have been made on the position of Babinet's neutral point, and at

TABLE II.—AVERAGES OF SOLAR RADIATION AND SKY POLARIZATION
WITH THE SUN 60° FROM THE ZENITH.

Station	Elevation	P_2	e	Q_2	Q'_2
	Feet	Per cent.	Mm.	Calories	Calories
Flagstaff	6900	68.9	3.83	1.406	1.387
Santa Fé	7000	68.8	8.42	1.349	1.371
Phoenix	1100	60.9	6.72	1.276	1.284
Washington	100	69.0	3.23	1.307	1.276

Madison no measurements were made of the polarization at the point of maximum. The data indicate that with the sun on the horizon the positively polarized light, which results principally from the primary scattering by small particles, is relatively the weakest at Washington and Madison, and strongest at Flagstaff and Santa Fé.

Comparing the data of Tables II and III, it is seen that the difference in sky polarization with the sun on the horizon and at 30° above is least at Washington and greatest at Phoenix.

If we study the local conditions that exert a modifying influence upon sky polarization, it must be noted that Washington and Madison are in regions of dense vegetation both with respect to the forested areas and the open country. Phoenix, Ariz., is in a treeless valley; the soil is light in color and extremely fine in texture, and at times the dust arising from it covers the surface like a fog. About Santa Fé the country is generally covered with

a scattered growth of stunted trees, while Flagstaff is in the midst of a forested area, although the growth is much less dense than is the case in the Eastern States. These two latter stations are near the foot of valleys, at the heads of which are mountains over 12,000 feet high. There is strong air drainage down these valleys at night, and in consequence the atmosphere at sunrise is remarkably clear. Soon after sunrise the valleys become hot, and there is a reversal of wind direction, which brings in more or less dust from the plains below. At Santa Fé the pyrheliometer readings at this time sometimes showed a falling off in radiation intensity of as much as 8 per cent. even before the wind at the surface had changed its direction. This was accompanied by decreased polarization of sky light at the point of

TABLE III.—SKY POLARIZATION OBSERVATIONS WITH THE SUN ON THE HORIZON.

Station	Distance of Arago's neutral point from the anti-solar point			Distance of Babi-net's neutral point from the sun			Maxi-mum polariza-tion in zenith	Period covered by the observations
	Max.	Min.	Mean.	Max.	Min.	Mean.	Per cent.	
	°	°	°	°	°	°		
Washington, D. C.	21.2	16.4	19.1	....	....	....	74.9	Jan. 8–May 19, 1910
Madison, Wis.....	21.7	18.0	19.6	18.8	17.6	18.0	....	July 25–Aug. 4, 1910
Phoenix, Ariz.....	19.5	18.2	18.8	19.1	16.2	17.7	75.4	Oct. 3–Oct. 8, 1910
Flagstaff, Ariz.....	21.6	16.1	17.9	18.8	14.4	16.0	78.9	Sept. 25–Sept. 30, 1910
Santa Fé., N. M...	18.5	16.1	17.2	16.2	14.7	15.5	78.2	Sept. 7–Sept. 20, 1910

maximum, and was usually followed by the formation of cumulus clouds. At Flagstaff the effect of the reversal in wind direction on the pyrheliometer readings and on the polarization was less marked, and there was less tendency to form clouds; but both solar radiation intensity and sky polarization showed a slight falling off in the afternoon, which was undoubtedly due to the increased scattering of light in the lower atmosphere on account of the dust introduced by convection.

At Phoenix the radiation was more intense during the afternoon than during the morning hours, without a corresponding increase in sky polarization. This may have been due to the effect of smoke from the city, which diminished noticeably in density as the day advanced, perhaps on account of a decided diurnal variation in wind direction. In this way the atmospheric transmission in the direction of the sun might be increased,

without noticeably affecting either the secondary scattering or the reflection from lower surfaces in a direction 90° from the sun. The distance of Babinet's point from the sun was slightly greater at sunset than at sunrise at both Phoenix and Flagstaff. The increased dustiness of the atmosphere due to convection appears, therefore, to have slightly decreased the sky polarization during the afternoon as compared with the forenoon hours at the three stations above named.

It is not believed that the great diurnal variation in sky polarization observed at Phoenix as compared with that at Flagstaff and Santa Fé, and especially as compared with that at Washington, can be attributed to convection, since we do not find a corresponding diminution in atmospheric transmissibility.

TABLE IV.—Sky Polarization with Different Reflecting Surfaces.

| Station | Date | Sky polarization | | Remarks |
		Noon	Sun on horizon	
		Per cent.	Per cent.	
Santa Fé, N. Mex.....	Sept. 8, 1910	68.2	77.6	Clear sky.
Santa Fé, N. Mex.....	Sept. 11, 1910	56.2	....	Sky $\frac{1}{10}$ covered with cumulus clouds at noon.
Phoenix, Ariz........	Oct. 7, 1910	59.1	73.0	Clear sky.
Washington, D. C.....	Dec. 23, 1908	50.6	66.6	Clear sky. Snow on ground.
Washington, D. C.....	Dec. 1, 1909	71.0	74.1	Clear sky. No snow.

Perhaps analogous conditions exist at Santa Fé when clouds commence to form, and at Washington when the ground is covered with snow. Polarization data for these several conditions are given in Table IV.

There was little difference in solar radiation intensities at Santa Fé on September 8 and 11, 1910. At Washington the radiation was more intense on December 23, 1908, than on December 1, 1909.

It seems rational to attribute the low percentage of sky polarization at noon at Phoenix to causes similar to those that produced like effects at Santa Fé and Washington, namely, reflection of light to the sky from low-lying surfaces. In the case of Santa Fé these were the surfaces of cumulus clouds; at Washington the light was reflected upwards from a snow surface, and at Phoenix from the light colored surface of the ground and the dust layer just above it.

In comparing sky polarization observations at different stations it is therefore necessary to take into account the relative intensities of reflection from the surface.

It now remains to account for the apparent relation between Q'_2 and P_2 indicated by the data for Washington in Table I, and of which we find little trace in the data for other stations, except possibly at Santa Fé. In other words, when the solar radiation intensity decreases from 1.302 to 0.902, why does the sky polarization diminish from 70.8 to 43.0, as shown in the averages of groups 1 and 4 in Table I?

From my original records it is found that of the ten series of observations included in group 1, seven occurred in November,

TABLE V.—DAYS WITH LOW VALUES OF P_2 AND Q'_2.

Date	P_2	e	Q_2	Q'_2	Wind, direction	Remarks
Oct. 10, 1907, P.M..	52.9	8.18	0.992	1.016	SE.	Rain on Oct. 11.
June 8, 1908, P.M..	52.2	12.68	1.016	1.089	SE.	Rain on June 9.
May 1, 1908, A.M..	52.1	3.63	1.113	1.087	NW.	Rain on May 2.
June 27, 1908, A.M..	52.0	13.61	0.982	1.066	SW.	Rain, P.M., June 27.
Apr. 29, 1908, P.M..	51.9	4.75	1.049	1.035	S.	Rain on April 30.
Apr. 17, 1906, A.M..	51.6	4.57	1.036	1.020	NW.	Followed period of heavy rain.
Apr. 17, 1908, A.M..	51.4	3.81	0.994	0.970	SE.	Lunar halo, 1 A.M., 18th; Rain, 18th.
Apr. 17, 1906, P.M..	51.0	4.44	1.017	1.000	NW.	Followed period of heavy rain.
Apr. 25, 1907, A.M..	43.4	6.76	0.931	0.939	S.	Lunar halo, P.M., 25th, Rain, 26th.
May 18, 1906, P.M..	42.5	8.50	0.838	0.866	NW.	Excessively hot.

1906, in the southeastern quadrant of decided high barometric areas, and the remaining three occurred in September, November, and December, 1909.

The two series in group 4 and the eight series in groups 2 and 3 having the lowest values of P_2 and Q'_2 were all obtained in the months of April, May, and June, except one, which was obtained in October. Data relative to these ten series is given in Table V, from which it is seen that lunar halos were observed on the nights following two of them, and that seven were followed by rain before midnight of the succeeding day.

On none of these days was there marked dustiness or smokiness in the lower layers of the atmosphere, and there was almost a complete absence of clouds, although on some days it was noted that the sky had a streaked appearance. It therefore appears that we here have to do with optical haze, or reflection from non-homogeneous layers or currents of air. According to

Hann,[11] its occurrence under certain conditions is indicative of the approach of fine weather, while under certain other conditions it is evidently the forerunner of nucleation and rain.

CONCLUSIONS.

From the data here presented it appears that while the polarization of sky light is greatly modified by reflection from the surface of the earth it is intimately connected with meteorological processes and conditions.

Decreased polarization may be produced by mechanical haze, due to the presence of large particles of any description in the atmosphere, or by optical haze, due to a lack of homogeneity in the atmospheric layers. While this latter condition is not of itself a sufficient criterion on which to base a weather forecast, in connection with other data it should be of assistance in determining the extent to which upper air conditions are disturbed. It is a question, however, whether pyrheliometric readings would not be more useful for this purpose, since these latter are only affected by the conditions along the path of the incident solar rays.

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[10] Loc. cit.

[11] Lehrbuch der Meteorologie. Zweite Auflage, Leipzig, 1906, p. 15.

THE CONSERVATION OF IRON.*

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THE history of the human race might be written in the history of iron. From far back of the early times when man learned to chronicle his triumphs and achievements on tablets of stone, there come down to us the dim traditions of the winning from iron bearing stones of the wonderful metal which was destined to be the greatest instrument of his struggles and of his uplift throughout the ages. Indeed the tablets of stone on which early man recorded his deeds and laws stand as proofs that the development of cutting tools and weapons preceded the art of writing.

Whether as sword, ploughshare, pen, compass needle, or machine, this wonderful and indispensable metal has led men along the paths of conquest, empire and evolution. The historian [1] may well conclude that the saying of Bishop Berkely, "Westward the course of empire takes its way," has received a new interpretation, for the iron industry, the source and sign of material power, which had its beginnings in Asia, the cradle of the race, passed along the Mediterranean into western Europe, crossed the Atlantic Ocean and now finds a home in the valleys of the Rockies and by the Golden Gate to the Pacific. It has made the circuit of the world, and now in the face of an awakened and stirring Orient, thoughtful men are asking if perchance it is preparing for a second cycle.

It is the object of this paper to point out the importance of the conservation of iron in so far as practical methods present themselves for accomplishing results. We may, however, by way of introduction permit ourselves a brief survey of historical data. Herodotus tells us of the early use of iron by the inhabitants of Asia, the Egyptians and other early civilizations. The early traditional writings of the Hebrews teem with allusions to the development of artificers of iron, from Tubal Cain, the first blacksmith of record, to Nebuchadnezzar, King of Babylon, who

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[1] Swank, Iron in All Ages.

in a noted inscription records: " With pillars and beams plated
with copper and strengthened with iron, I built up its gates."
The prophet Daniel says: " Iron breaketh in pieces and sub-
dueth all things," and " Thou shalt break them with a rod of
iron," is the adjuration of the Psalmist.

The earliest steel workers of record were the Chalybians who
lived on the southeastern shores of the Black Sea, although other
ancient eastern peoples had been almost equally renowned in
history and tradition. In the British Museum there are examples
of iron and steel tools which are probably more than 3000 years
old. The ancient swords of Damascus are famed in song and
story and we are told were of such keenness and temper that
they could cleave a floss of silk floating in the air or sever a
massive iron helm, with equal facility.

Far back, however, of authenticated historical data, the
ancient Chinese peoples developed the metallurgy of iron to an
art, and this metal is said to have been mentioned in Chinese
writings more than 3000 years before Christ. In later times,
Pliny the elder, who lived in the first century of our era, testifies
as to the excellence of the iron made by the Chinese.

The beautiful iron monument of Kutab Minar near Delhi,
India, is of great antiquity, although its exact period is in doubt.
Randolph, an American who visited Delhi in 1874, records that
he attempted to secure a few grains from the base of the monu-
ment for analysis but that it completely dulled two cold chisels
worked by his servant without producing any marks on the base
of the pillar.[2] Although this extraordinary statement taxes our
credulity, there can be no doubt that the old, hand wrought,
charcoal smelted irons were of a grade of excellence that modern
steel makers find it difficult to attain. It is also noteworthy here
that the iron column of Delhi has resisted the corrosive influence
of the atmosphere for many centuries, with no protective coating
beyond that which nature may herself have provided. In regard
to density, homogeneity, temperability and resistance to corro-
sion, the fame of the older metals has come down to us, and in
truth there is a mass of testimony to prove that inferior qualities
began first to seriously show themselves contemporaneously with
the introduction of the great modern pneumatic processes used
in manufacturing both iron and steel.

[2] Swank, Iron in All Ages, p. 9.

We live, however, in a practical age and it is essential that we should consider our great industrial problems from a practical view-point. No sensible persons would venture to propose a return to the old hand worked methods of manufacture, for modern conditions could not support such an industry. In the old Wootz and Catalan processes, very pure magnetite and hematite ores, first pulverized and thoroughly lixiviated and washed were used. They were then little by little puddled out by burning with charcoal in a pit or oven and subsequently beaten and forged by patient industry to the desired form. It seems to be a law of Nature that her materials should respond to the manipulations of the hands of man and acquire properties that machinery cannot give. As an example of this, we have only to remember the everlasting qualities of the hand worked lacquers and enamels of the Orient and compare them with the machine and brush laid coatings of our own industrial processes. The poet Virgil who lived before Christ has drawn a picture which brings vividly to mind the intense manual labor involved in early metallurgical operations:

> [a] As when the Cyclops, at th' almighty nod,
> New thunder hasten for their angry god,
> Subdued in fire the stubborn metal lies:
> One brawny smith the puffing bellows plies,
> And draws and blows reciprocating air:
> Others to quench the hissing mass prepare:
> With lifted arms they order every blow,
> And chime their sounding hammers in a row:
> With labored anvils Etna groans below.
> Strongly they strike; huge flakes of flames expire:
> With tongs they turn the steel and vex it in the fire.

The Nineteenth Century ushered in the age of steam and from this point the history of iron exerts an even more potent influence than before over the development of the human race. The names of Watt, Stevenson, Bessemer and Siemens will never require bronze monuments to perpetuate them, for as long as iron is made or moves they will be remembered.

It was significant that the steam-engine, the locomotive and the great pneumatic process for steel making should have appeared at almost the same moment, as though indeed an over-

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[a] Quoted from Swank, *loc. cit.*

shadowing Providence had a deep laid design for the industrial
future of the race. It is a curious thought too that experience
and tradition teaches us that all the gifts of Nature or Providence
have penalties attached. The Golden Age told this truth in
song and story, as in the Hebrew tradition of the banishment
from Eden, or in the Homeric legends of the Greeks. And now,
in turn, the Iron Age exacts its penalties and the gigantic indus-
trialism of modern man threatens the future with its penalties.

FIG. 1.
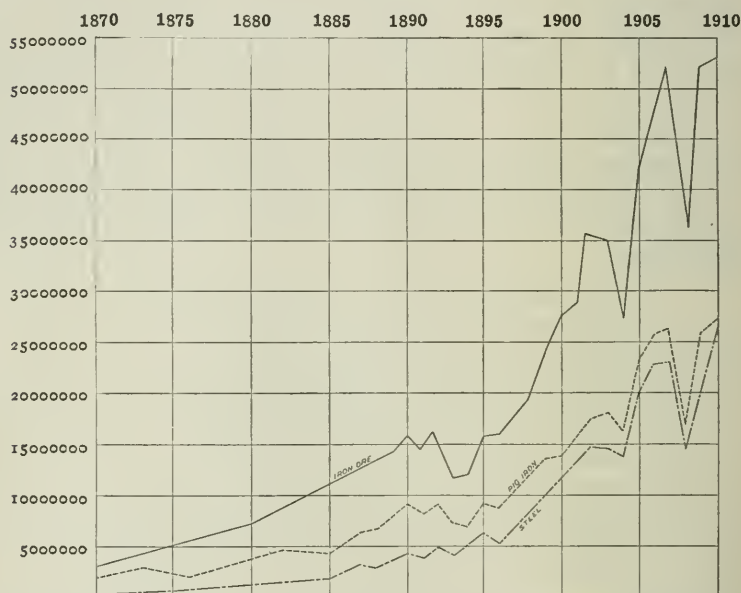
Curve showing the production of iron ore, pig-iron, and steel in the United States, 1870 to 1910,
in long tons.

Probably no one who has not made a special study of the
conservation of iron has a fair conception of the problems which
the question presents.

I have chosen for my theme to-day the presentation of this
subject, along a line which I venture to hope will bring out the
relation of iron conservation problems to the general subject of
intensity of growth in civilization. I have chosen to begin my
analysis from the year 1870, because from this date on there

begins the steep rise in what for want of a better characterization I shall call the intensity curves of civilization.

In order to simplify my purpose and because the statistics are more readily available, I have confined myself to the data which applies only to the United States, but these may be taken as fairly indicative of the world's curves.

FIG. 2.
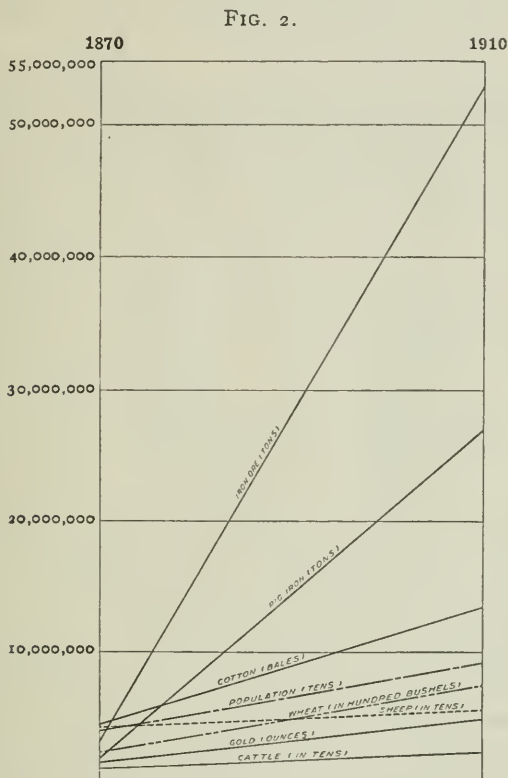
Intensity curves on staple products in the U. S. from 1870 to 1910.

As it is impossible to include in a tabular or graphic representation all the staples, the production and consumption of which may be taken as the measure of intensity, I have made an arbitrary selection in order to illustrate my point. I start with the premise that the necessities and the energies of human life can be very simply analyzed. Food and clothing, the prime human

necessities, can for our purpose be represented by wheat and cattle,[4] sheep and cotton, and the source and sign of material energy by iron. Gold, the measure of value and medium of exchange, is included, for reasons which are sufficiently obvious, and finally the growth in population is also shown.

I first present in Fig. 1 the curve showing the growth in the production of iron ore, pig-iron and steel, the data having been compiled from the figures furnished by the U. S. Geological Survey.

In Fig. 2 I show the curve in production of the various staples mentioned in the preceding paragraph. I have not in this table shown the fluctuations in production, from year to year, but for the sake of convenience in demonstrating my point have drawn straight lines for the production in 1870 and in 1910. In order to show the statistics of the different staples graphically, it has been necessary to adopt the arbitrary plan of counting population, sheep and cattle by tens, instead of by units, and also to express the growth in wheat production in hundred bushels instead of in one bushel units. By adopting this expedient, we are enabled to start all of the productions from a more or less common starting point, somewhere between two and six million units. As will readily be seen, iron ore and pig-iron are shown in tons, cotton in bales, gold in ounces, live animals and population in tens, and wheat in hundred bushels. The statistics on cotton, wheat, sheep and cattle are from bulletins of the Bureau of Statistics, U. S. Department of Agriculture; the figures on population from the U. S. Census Report.

Although all the intensity curves are ascending, the iron curve is a veritable Mt. McKinley whose topmost peak is still unknown and unexplored. The total production of pig-iron in 1910 was 27,290,545 gross tons against 25,795,471 tons in 1909, an increase of 1,503,074 tons, or over 5.8 per cent. It is, however, when contrasted with the increase in population that the iron statistics come out most strongly. The per capita production of pig-iron in the United States has increased more than 1000 per cent. since 1850. If the rate that was recorded in the last decade is in any degree approximated in the present, the per capita production will exceed one-half ton before 1920 is reached.

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[4] The cattle statistics used refer only to milch cattle.

Table I gives the total and per capita production of the last seven census years:

A Spanish statistician [5] has recently published an interesting review of the question of the iron ore supplies of the world. To bring home the far-reaching importance of the matter, he draws attention to the fact that the annual production of iron has risen from 5 million tons at the middle of the Nineteenth Century to nearly 61 million tons in 1909, and for this about 140 million tons of ore were consumed in that year. This author points out that there is no reason to suppose that the world's output of iron has reached its maximum point but that on the contrary it is likely during the coming decades that the rate of the annual increase in production will be fully maintained and probably

TABLE I.

Calendar years	Population of United States, number	Production of pig-iron, gross tons	Per capita production, pounds
1850	23,191,876	563,755	61.6
1860	31,433,321	821,223	63.6
1870	38,558,371	1,665,179	105.6
1880	50,189,209	3,835,191	178.0
1890	62,979,766	9,202,703	318.1
1900	76,303,387	13,789,242	386.8
1910	91,972,266	27,298,545	664.7

surpassed. He assumes the world's production of iron in 1920 will be 93 million tons produced from about 217 million tons of ore, that is to say, that if this forecasted rate of increase in the production of iron is realized, the present annual world's output of iron ore will be required to be increased about 88 million tons.

We must now turn to the consideration of the resources which must stand the drain that modern intensity is putting upon them. At the Eleventh International Geological Congress at Stockholm, which met last year, there was presented a lengthy report [6] upon the amount and distribution of the world's supply of iron ore. Practically every country where iron ore is worked is represented. The total known supply of iron ore of the world is estimated on Table II.

[5] J. de Lazurtegui, Ensayo sobre la cuestión de los Minerales de Hierro Ayer, Hoy y Mañana, Bilboa, 1910, pp. 1–145.

[6] Iron Ore Resources of the World, Stockholm, 1910.

The *Journal of the Iron and Steel Institute* comments upon Table II as follows: To what extent the future of iron will become dependent upon low grade ores is shown in this report. The actual reserves of rich ores containing 60 per cent. of iron are estimated at 1300 million tons, and the potential reserves at 687 million tons. Four-fifths of the known and recorded rich ores are contained in the deposits of northern Sweden.

As has already been stated, it is the object of this paper to consider the conservation of iron principally from the stand-point of our own immediate problem in the United States. The statistics already given show very clearly that the annual production of iron ore may very possibly reach the 100 million ton mark if the present general tendency towards increase is maintained for a few more decades. If we could assume that this figure would not be surpassed but would become an upper limiting value, the

<div align="center">TABLE II.</div>

	Actual reserves		Potential reserves	
	Ore, metric tons (millions)	Iron, metric tons (millions)	Ore, metric tons (millions)	Iron, metric tons (millions)
Europe........	12,032	4,733	41,029	12,085
America........	9,855	5,154	81,822	40,731
Asia............	260	156	457	283
Australia.......	136	74	69	37
Africa.........	125	75	many thousands	many thousands
Totals.....	22,408	10,192	123,377	53,136

situation would hold no menace for the western hemisphere for many generations yet to come. The actual and potential ore reserves of America given in Table II are sufficient even at this rate to last nearly one thousand years, and we may as well admit that we need feel little responsibility in regard to our remote descendants who may exist in ten centuries from the present era. With respect to the United States and the situation which children now born will have to cope with, we are, however, vitally concerned. Mr. John Birkinbine,[7] in an interesting article on the "Production and Resources of the Lake Iron Region," has published some valuable figures. He gives the total contribution to

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[7] The Mining World, vol. xxxiii, No. 10, p. 417.

the iron ore supply of the United States made to the close of 1909
by each of the ranges included in the Lake Superior district,
which produces about 80 per cent. of all iron ore mined in the
United States.

Mesabi	195,703,424
Marquette	91,903,991
Menominee	71,313,115
Gogebic	60,820,503
Vermillion	29,125,385
Total	448,966,418

Birkinbine also states that a report was issued in 1908 by
the Minnesota Tax Commission, which claimed that a con-
servative estimate of the available iron ore lands in the lake
iron region showed a reserve of 1,192,500,000 tons of iron ore,
the bulk of which is on the Mesabi range.

Dr. C. W. Hayes, the well-known statistical expert of the
U. S. Geological Survey, has given an extremely interesting
review of the iron situation.[8] He says in part: " If the average
rate of increase by decades should be continued, it would require
the production in the next three decades of 6,088,000,000 tons
of ore. But the ore supply now available in the United States is
estimated at 4,788,000,000 tons, which is only 78 per cent. of
the amount needed on this assumption. It is evident, therefore,
that the present average rate of increase in production of high
grade ores cannot continue even for the next thirty years, and
that before 1940 the production must already have reached a
maximum and begun to decline, and a very large use must be
made of low grade ores not now classed as available. The
second condition, with its consequently greatly increased cost of
iron, is the only thing which can prevent a decline in the iron
industry, measured by the amount of pig-iron produced within
the next thirty years, unless there is in the meantime very greatly
increased importation of foreign ores."

Dr. Hayes, however, further points out what I wish to em-
phasize here, that it is impossible to accurately predict the date of
exhaustion of the iron ore supplies and that any attempt to do
so is wholly unprofitable and unwarranted. It will readily be

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[8] Mineral Resources of the United States, 1908, U. S. Geological Survey.

seen that there are too many factors which enter into this problem, both from the stand-point of political economy and technical development, the tendency of which is not always determinable. It is, however, safe to say that an analysis such as has been attempted in this paper should do good by stimulating more careful study by the public generally of an interesting situation which undoubtedly exists. The normal intensity flow as shown in Fig. 2, which in a sense measures the growth of humanity and civilization in the United States, may be considered to be that which is bounded by the lines for cattle and cotton. The intensity curves for iron, as can clearly be seen at a glance, are out of all proportion to the other staples which in their aggregate may be taken as a measure of modern development.

Another interesting feature of the iron conservation problem which is frequently overlooked is the relation between iron and coal. It is estimated that every ton of iron ore produced requires about four tons of coal or its equivalent in fixed carbon to convert the ore into merchantable iron and steel. An ultimate annual consumption of 400 million tons of coal per year for this purpose alone is therefore to be anticipated in the not distant future.

In presenting this paper on the conservation of iron, there has been no intention on the part of the author to approach the subject in a pessimistic or malthusian attitude of mind. The world is working out other problems and it will undoubtedly work out this one. The exhibition and application of energy or even the very existence of the human race without iron is unthinkable from the stand-point of our present knowledge. In the main, the problem is one for the political economist and as this phase of the subject carries us onto ground somewhat unfamiliar to the writer, we will pass to the technical side of the discussion. It would seem, however, that free entry of raw materials into this country is sure to be demanded in the near future, whether some of us like it or not. The high grade ores of northern Sweden, of Asia, of South America, and of British North America will be as necessary to our industry as to that of our national competitors. From this point of view perhaps the wise statesmanship which is seeking to bring about reciprocity with our American neighbors has not been as highly appreciated as it deserves, by large numbers of our people.

From the technical stand-point, the conservation of iron pre-

sents interesting problems which we will now proceed to briefly
consider. The tendency of iron to oxidize or rust is inherent in
its nature. The rusting of iron is essentially a process of slow
combustion which is annually burning up an untold and unknown
quantity of this precious metal. Forest fires in one great blazing
conflagration can destroy hundreds of millions of dollars worth
of valuable timber. Kindly Nature assisted by the arts of man
can cause the forest to grow again, but no partnership between
industry and Nature will ever again reclaim the iron that has
fallen away to rust. If it were possible to obtain statistics capable
of showing even approximately the quantity of iron which annu-
ally burns to rust, they would probably astonish us. Unfortu-
nately, such statistics will never be available. It is not even
possible to obtain reliable data in regard to the quantity of iron
which goes to the scrap pile each year. It is, of course, well
known that a very considerable quantity of selected scrap goes
back to the furnace to be used again, and in even the best open-
hearth steel practice about 50 per cent. of the total charge con-
sists of high grade scrap. In addition to this, low grade scrap
is used for common castings and for other purposes, but in spite
of all this there must be a vast quantity of junk which is destined
never again to become serviceable to man.

I quote from an interesting article in a recent issue of one of
the great New York newspapers: " An enormous quantity of
new iron is continually being mined and manufactured and
apparently added to the world's stock of material, and yet the
available pile of usable metal does not rapidly increase. The
fact is that only a small portion becomes permanently available
stock. Not more than a quarter of the world's iron is used a
second time, and not more than a quarter of this goes through a
second scrapping. Where does it all go? We get many sug-
gestions as to where and how the iron is dissipated, or, as we
say, consumed; this consumption being as complete and final for
the portions considered as the consumption of coal or wheat. In
the processes of manufacture, in the melting and forging, there
is burning of metal, and in all the cutting operations of the shops
there is waste, only the larger chips representing recoverable
material. The dissipation by wear is more rapid than one would
think. Dr. Soper, in a recent valuable paper before the Boston
Society of Civil Engineers, says that he found that, by actual

record of material replaced, there was produced in the New York Subway, from the brake shoes alone, one ton of iron-dust per month per mile. The waste of wheels and rails was not so easily ascertainable, but it is to be added to this.

" The same rate of iron-dust production was estimated for the elevated railroads, while the same process was also in operation on the surface roads and, more slowly, of course, with all running vehicles. On the big railroads account is kept of the weight of the cars in use. A large number of steel hopper cars showed an average loss of weight of 702 pounds the first year, with continuous losses, not always at the same rate, for subsequent years. Some of this loss, of course, was due to wear and some to rust. The rusting of iron goes on always, and in some extensive lines of manufacture, as for instance wire fences, and the various iron articles in domestic service, the entire output ultimately goes to rust. Old iron lies around everywhere, some of it too small and much of it too insignificant to be individually noticed, slowly disintegrating, some of it going into the air, some into water, and some into the soil,and through these media into untraceable combination and activities. Dr. Soper, in the paper referred to above, says that he has never found any dust anywhere in New York which had not iron in it."

What seems to be necessary on the technical side of the iron conservation problem, is some inventive development which will assure a more permanent quality in the iron and steel which is manufactured into serviceable forms. A certain amount of wear and tear and unavoidable waste there will always be, but it is by no means impossible that metallurgical and technical development will in the future reduce the wastage to a reasonable minimum. If the great modern steel structures could be looked up as practically permanent, we should have the comfortable assurance that many tons of iron and steel once won from the ore represented a practically permanent addition to the wealth of the world. Great progress has been made within the last few years in the understanding of the corrosion problem and in the art of protecting iron and steel from rapid decay. Several years ago the writer had the honor of presenting before The Franklin Institute a paper on the " Electrolytic Theory of Corrosion." This theory has found a direct application to the manufacture and production

of protective coatings both in the form of paints and of other metals, and careful, systematic tests of these new ideas of protection are more and more strongly corroborative as time goes on. Much remains to be done, however, before the full protection of iron and steel against corrosive influences may be considered a problem solved. The electrolytic explanation of corrosion has shown why it is that hastily made, badly segregated steel rusts more seriously and more quickly than pure, carefully made metal. This knowledge has led to a new development in the metallurgical industry of this country. Processes have been worked out, by means of which iron of extraordinary purity and most excellent quality is now made in open-hearth furnaces on the large scale of operation usual in steel making. The purity of these products is equal and even superior to that of the best Norwegian and Swedish charcoal irons, and there is no question but that they fill a long felt want for a great many industrial purposes. No claim can be made that these pure irons are absolutely rust resistant, but their particular value along this line seems to be that they are slow rusters and that being practically free from impurities, the bad effects due to segregation are reduced to a minimum. It is not always the fact that iron or steel rusts but the manner of its rusting which constitutes a special danger. Just as a chain is no stronger than its weakest link, so also a piece of iron in service may be ruined and discarded even if more than 99 per cent. of its mass and surface is still in good condition. The even texture of the rust which forms upon these pure irons and the absence of pitting effects is one of their prominent characteristics. When provided with an efficient protective coating in addition to their own slow rusting qualities, they appear to be a decided step in advance in the achievement of rust resistant iron. As a basis for the manufacture on a commercial scale, of comparatively cheap and very highly rust resistant alloys, these pure irons hold out a great promise. There are whole series of binary and ternary alloys of iron which have not yet been thoroughly studied even on the laboratory scale. It has already been reported that certain ternary alloys of iron, nickel and copper started from a pure iron base are non-rusting.[9] There is always the hope that a commercial unrustible alloy with the

[9] Clamer, Proc. Am. Soc. for Testing Materials, x, 270 (1910).

strength and valuable physical properties of steel will solve the
problem of a permanent industrial metal.

One difficulty that has been met with and overcome in the
manufacture of these pure metals lies in the fact that when the
attempt is made to burn out all the ordinary impurities that pro-
duce segregation, the iron itself is likely to be burned. When this
has occurred, the oxygen content of the resulting metal will be
high, and segregation of the oxide is almost certain to take place.
Fortunately this difficulty has been overcome, and pure iron can
now be made with as low an oxygen content as the best steels.
On analysis by the Ledebur method of combustion in hydrogen,
the writer has examined samples of these pure irons which run
as low as 0.015 oxygen. It is probable that an oxygen content
of from 0.03 to 0.04 might be considered allowable in metals of
this type.

Another project that is interesting along the line of preserva-
tion is the study of possible methods of treating structural steel
on a manufacturing scale so as to give it a practically unrustible
surface. There are a number of processes that have been pro-
posed and some of which are now in use for bringing about this
result. The well known Bauer-Barff and Wells processes depend
upon already oxidized surfaces. One promising field is along the
line of alloying the surface after the steel has already been rolled
and shaped. Others again depend upon rolling oxide into the
surface and giving the surface another working between specially
designed rolls, such as in the Speller process. It is true that all
these expedients add to the cost of the products, but, in view of
the importance of the problem, it is probable that within reason-
able limits the cost will not be a factor.

It is well known that serious damage can be done to structural
steel by electrolysis caused by stray currents from high potential
electric service lines. In fact, it is perhaps not too much to say
that electrolysis threatens the destruction of millions of dollars
worth of property in this country. After a few more serious
object lessons have been met with by engineers, it is likely that
any expedient that promises to reduce the dangers will be wel-
come. The writer has himself recently been called upon to inspect
and report on a full reinforced concrete structure which cost
$400,000 to build about four years ago and which has been ruined
by electrolysis from escaped railway currents. If this form of

steel tuberculosis is going to attack the great reinforced concrete buildings of the present day, the ultimate damage will be appalling.

The principal methods which are used on a large scale at the present time for the protection of steel consist in the various types of so-called protective coatings. We may consider these under the separate headings of metallic coatings and paints. The electrolytic explanation of corrosion has proved most useful to the technology of protective coatings. The various processes for zinc deposition have been more used than any others. Zinc on theoretical grounds is the most protective metal, owing to the fact that it is strongly electro-positive to iron and will therefore protect it at its own expense as long as it is kept in contact with it. In one very important respect, the subject of zinc protection has not been understood by engineers, manufacturers, and others who are responsible for the production and purchase of galvanized material. It has been generally supposed that any cracking or crazing of the zinc coatings would invite corrosion by allowing moisture and the atmosphere to penetrate to the underlying iron. The effort to overcome this supposed difficulty has led to the application of thin, light coatings of zinc. On the Isthmus of Panama there have been found examples of galvanized sheet that were left there by the French when they abandoned the workings. This galvanized sheet, which must be some thirty to forty years old and which has been exposed under very trying conditions, has steadfastly resisted corrosion. It is true, of course, that these old examples of galvanized sheet were probably hand dipped and were provided with very heavy and efficient zinc coatings. It could not be claimed that the machine galvanized sheet as made to-day would last anything like as long as this, under the same conditions. An example of misdirected zeal on the part of those responsible for specifications for galvanized steel wire has recently been brought to the writer's attention. A specification under which a very large quantity of wire was to be bought stated, among other qualifications, that the wire must be capable of being closely wrapped around another wire of the same diameter, without showing cracking or crazing at the bends. Now, zinc as has been stated, is electro-positive to iron, and when the two metals are in contact, the iron will be protected even if it is entirely exposed and bare. This point has been very clearly brought out

as the result of systematic investigations by the writer and others, and it can be demonstrated by anyone who wishes to take the trouble to solder pieces of zinc and iron together and submit the couple to corrosive influences. Inspection shows that the bare, cut-off ends of galvanized wire do not rust on exposure. Why, then, draw specifications which only succeeded in excluding heavy coatings of zinc, simply because these show cracking and lifting at sharp bends? It would be far better for engineers to specify within possible limits the actual weight of zinc which their galvanized material is to carry, but in default of this it would be better at the present time to buy material that cracks and crazes on severe bending tests than to draw up specifications to preclude this condition.

Next to zinc, the metals most used to protect iron are tin, lead, and the alloys of these two metals which are used in the production of terne plate. Theoretically speaking, neither tin nor lead should ever be used for the protection of iron, for instead of being, like zinc, electro-positive to iron, they are electro-negative. It will therefore be seen that any crack or opening in a protective coating of tin will lead to rapid destruction of the iron at the exposed spot. It appears to be almost impossible to apply a tin coating to the surface of iron, that is free from minute openings known as pin holes. It is for this reason that so much trouble is experienced with the various types of iron which depend upon tin as the protective agent. If a perfectly homogeneous coating of tin could be put upon the surface of iron, the protection might be considered efficient, in spite of the fact that tin is electro-negative to iron, but this would simply be for the reason that tin in itself, when pure, is not a corrodible metal. In contact with iron, however, the burden of attack is thrown upon the iron in the couple, and iron in contact with tin will corrode more rapidly than when left to itself.

Copper, as well as lead and tin, has been proposed as a protective coating for iron, but is open to exactly the same criticism, as it is one of the metals which is strongly electro-negative to iron. Among the electro-positive metals which have not been mentioned, we find both aluminum and magnesium, but up to the present time no alloy of these metals has been evolved, which is suitable in its physical characteristics, even if the cost were not considered prohibitive.

In the field of paint coatings, very great progress has been made in the protection of iron and steel within the last two years.

Four years ago the writer called attention to the fact that the action of the pigment portion of a paint coating, in either promoting or retarding corrosion, had been overlooked.[10] Previous to that time, the attention of engineers and paint technologists had been principally directed to the production of combinations of pigment and vehicle so designed as to be good excluders of moisture and to have other desirable qualities as then understood.

It has already been suggested in this paper that the element iron has been endowed with some very extraordinary properties which especially fit it for the intensive service of mankind. Among these characteristics which it possesses to a unique degree, we may include its power of hardening or taking a temper and the wonderful property of becoming magnetic. Still another wonderful characteristic may be defined as that of passivity or the power of being thrown, by contact with other substances, into a passive condition. The passive condition is not a stable one, nor is it possible by any means to render iron passive and to maintain it in this condition out of contact with the passifying agent. The fact remains the same, however, that while in the passive state iron loses one of its principal characteristics of being extremely active chemically and therefore becomes for the time being uncorrodible. The phenomenon of passivity has been known and studied for many years, and much literature exists on the subject. It is interestingly summed up in the article on iron in the Eleventh Edition of the Encyclopædia Britannica, which has just been published, but time will not allow of a discussion of the subject here. It will suffice to say that the best agents for producing and maintaining the condition, that have been put to practical test for paint coatings, are the slightly soluble chromates and other substances which when acted on by water produce a distinctly alkaline reaction. Pigmentary substances which produce a condition of passivity on the surface of the iron are now generally known and spoken of as inhibitive, because although they cannot be expected to entirely prohibit the rusting of iron, they do serve to maintain the passive condition and therefore check or retard corrosion. A very interesting series of tests involving these prin-

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[10] Proc. Am. Soc. for Testing Materials, vols. vii and viii, 1907–8.

ciples has been carried out by the American Society for Testing Materials in co-operation with the Paint Manufacturers' Association of the United States. A number of iron and steel panels treated with paint made from various pigmentary substances, have been exposed to the action of the atmosphere and elements at Atlantic City, N. J., for three years. The latest available report of these tests, which has been published, states that the inspection of the tests has shown that those pigments whose protective value depends upon the value of chromate inhibition, as well as those which produce basic reactions in water suspension, have given a good account of themselves on the test panels. Progressive paint technologists and engineers are now availing themselves of the results of the many investigations which have recently been published along these lines, and a most decided improvement may be expected in our ordinary methods for preservation of iron and steel.

The object of this paper has not been to present new data in regard to the preservation of iron and steel but to briefly summarize and review the general conservation problem. There can be no question that much of the iron which has been allowed to fall into the condition of irretrievable rust or gone to the scrap pile, from which it is unlikely to be again removed and made serviceable, might have been saved if the corrosion and preservation problem had been properly understood by engineers and technologists responsible for its care. It has only been of recent years that engineers have realized that it was unsafe to bring in contact in one construction metals of unlike electrochemical properties. It is, however, true that much destruction of iron has been occasioned by lack of knowledge of this one thing, for even different types of iron and steel will rust each other when connected together and exposed to the action of corrosive influences in the air or water. An Institute of Metals has recently been founded in England, for the special purpose of considering just such important industrial problems as those here referred to. In summarizing this paper which has been written in the hope that it will serve to stimulate general interest on the part of thoughtful persons to the importance of the iron conservation problem, it has been shown that iron, the cheapest and most abundant of the industrial metals, is, after food and clothing, the most indispensable substance which enters into the life-history

of man. A very recent authority has said of iron [11] : " Iron is a
very Proteus. It is extremely hard in our files and razors and
extremely soft in our horseshoe nails which in some countries
the smith rejects unless he can bend them on his forehead. With
iron we cut and shape iron; it is extremely magnetic and almost
non-magnetic; as brittle as glass and almost as pliable and ductile
as copper; extremely springy and springless and dead; wonder-
fully strong and very weak; conducting heat and electricity easily
and again offering great resistance to their passage; here welding
readily, there incapable of welding; here very infusible, there
melting with relative ease. The coincidence that so indispensable
a thing should also be so abundant, that an iron-needing man
should be set on an iron-cored globe, certainly suggests design.
The indispensableness of such abundant things as air, water,
and light is readily explained by saying that their very abundance
has evolved a creature dependent upon them, but the indispensable
quality of iron did not shape man's evolution, because its great
usefulness did not arise until historic times or even, as in the
case of magnetism, until modern times."

Whereas it has been shown that the great increase in the per
capita consumption of iron by the human race is but a part of
the general advance in wealth and civilization, it has also been
shown that the intensive use of iron is out of all relation or
proportion to the increase of intensivity in the use of the other
materials which go to make up the necessities of the race and of
civilization. It must, of course, be admitted that the causes of
this great increase in the use of iron may be found in the diver-
sion of mankind from purely agricultural to manufacturing pur-
suits, for nearly all machinery must necessarily be made of iron.
Again we have to take into consideration the displacement of
wood by iron for ships and bridge building, the use of iron beams,
columns and other members used in the construction of modern
buildings; the growth of steam and electrical railways, as well
as the introduction of iron fencing. In conclusion, it is inter-
esting to note that the three great nations which are the principal
iron producers of the world and which are so closely related by
ties of blood—Great Britain, the United States and Germany—
produced in 1907 81 per cent. of the world's pig-iron and 83

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[11] Encyclopædia Britannica, 11th Ed., 1910, vol. xiv, p. 801.

per cent. of its steel; and moreover the four great processes by which practically all the irons and steels are made, namely, the puddling, crucible, the acid and basic varieties of the Bessemer, and open-hearth processes, as well as the great mechanical methods of forging and rolling iron and steel, were invented by Anglo-Saxons, with the possible exception of the open-hearth process in which Great Britain must share with France the credit of the invention.

Gases Occluded in Copper Alloys. G. GUILLERNIN AND B. DELACHANAL. (*Comptes Rendus,* cli, 881.)—From the examination of several special forgeable brasses, bronzes, a phosphor-bronze and two samples of tin, it is concluded that: 1. Special brasses retain occluded from 1 to 30 times their volume of gas, chiefly hydrogen, carbon monoxide and dioxide. 2. In sound castings the gas is almost entirely hydrogen. 3. In unsound castings a larger portion of carbon oxides occur. 4. Hot rolled bars contain less gas than castings. 5. The hydrogen in sound pieces, even when in notable amount, has no injurious effect on the mechanical properties of forgeable brasses. 6. Phosphor-bronze contains very little gas, chiefly carbon dioxide and hydrogen, phosphorus, as in cast-iron and steel, seems to diminish the solubility of hydrogen in the metal. 7. Commercial tin contains a small volume of hydrogen and carbon oxides. 8. None of these metals exhibit the phenomenon of "spitting."

Alloys of Tellurium with Cadmium and Tin. M. KOBAYA-SHI. (*Zeit. anorg. Chem.,* lxix, 1.)—Thermal analysis shows that tellurium and cadmium combine to form the compound TeCd, which melts at about 104° C. but exists in the melts only in equilibrium with an excess of tellurium. With tin, tellurium forms the compound, TeSn, melting at 780° C. and this forms a eutectic with tellurium containing 86 per cent. of the latter and melting at 393° C. Neither compound forms mixed crystals with its components. Cadmium dissolves tellurium up to 1.2 per cent. at 700° C., and the solubility is probably greater at higher temperatures.

Purification of Waste Water from Pulp Mills. J. G. ROEST. (*Chem. Wochblad,* vi, 106.)—It is well known that clay will remove impurities from liquids. Experiments on its use as a purifier of waste water from pulp mills show that 1½ per cent. of potter's clay is sufficient to precipitate suspended impurities from the waste water. The precipitated waste has an appreciable value as a fertilizer.

A GENERAL FORMULA FOR THE SHEARING DEFLEC-
TION OF BEAMS OF ARBITRARY CROSS SECTION,
EITHER VARIABLE OR CONSTANT.

BY

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1. INTRODUCTORY.—In determining the deflection of beams,
the effect of shear is usually neglected. The reason for this is
that the deflection is usually determined from the equation of the
elastic curve, which is based solely on the curvature produced
by flexure, and neglects entirely all other forms of deformation
such as are produced by shear, torsion, etc.

No general formula for shearing deflection has as yet been
derived, although special formulas for the case of constant rec-
tangular and circular cross sections have been obtained, as men-
tioned below. In what follows the principle of least work is
used to obtain a general formula for the shearing deflection of
beams of arbitrary cross section, which may be either variable or
constant. The same method is also applied to derive the Fraenkel
formula for flexural deflection, and it is further shown that all
the ordinary formulas for either flexural or shearing deflection
are special cases of one or the other of the above. Numerical
application of these formulas is then made to the rail of a planer,
in which both the cross sectional area and its moment of inertia
are variable.

2. DERIVATION OF GENERAL FORMULA FOR SHEARING
DEFLECTION.—The principle of least work as applied by Cas-
tigliano to the deflection of beams may be stated as follows:

*The deflection of the point of application of an external force
acting on a beam is equal to the partial derivative of the work of
deformation with respect to this force.*

This theorem is perfectly general, and applies to the shearing
as well as the flexural deflection since both give rise to work of
deformation.

The first step is to determine the work of deformation due
to shear. For this the following notation will be used.

Let

$W_s =$ work of deformation due to shear
$G =$ modulus of shear (or modulus of rigidity)
$q_1 =$ unit shearing stress
$\varphi =$ unit angular (or shearing) deformation
$dA =$ element of area of cross section
$dV =$ element of volume
$dx =$ element of length

Then Hooke's law for shear may be written

$$\varphi = \frac{q_1}{G}.$$

Consequently the unit work of deformation for an infinitesimal parallelopiped of volume dV becomes

$$dW_s = \frac{1}{2} q_1 \varphi \, dV = \frac{q_1^2}{2G} \, dV,$$

and therefore, since $dV = dA \, dx$, the expression for the total work of shearing deformation for the entire beam becomes

$$W_s = \int dx \int \frac{q_1^2 dA}{2G}.$$

Now the method to be used in determining the shearing deflection consists first in assuming a concentrated load K applied to the beam at the point whose deflection is to be determined. This assumed load is used for evaluating the expression for the deflection given by Castigliano's theorem, and having served this purpose is subsequently reduced to zero.

For this purpose let

$Q =$ total shear on any variable section due to the given loading
$Q' =$ shear on any variable section due to a *unit* load at a given point
$q =$ unit shearing stress due to total shear Q, as above
$q' =$ unit shearing stress due to shear Q'

Then for a concentrated load K at any given point, the shear on any section is $Q'K$, and the unit shear at a variable point due to this load is $q'K$. Hence the total unit shear due to both

the actual given loading and the assumed concentrated load K becomes

$$q_1 = q + q'K.$$

Hence the expression for the work of deformation now becomes

$$W_s = \int dx \int \frac{(q + q'K)^2 dA}{2G}$$

Now by Castigliano's theorem, stated above, the actual shearing deflection D_s due to the *given* loading is

$$D_s = \left[\frac{\partial W_s}{\partial K} \right]_{K=o}$$

Performing this differentiation and substitution, we have therefore

$$D_s = \int dx \left[\int \frac{2(q + q'K) \frac{\partial}{\partial K} (q + q'K) dA}{2G} \right]_{K=o}$$

$$= \int dx \int \frac{qq' dA}{G}$$

To simplify this expression, make use of the straight-line law, namely,

$$\frac{q}{Q} = \frac{q'}{Q'}, \quad \text{or} \quad q' = \frac{Q'}{Q} q,$$

whence finally

$$D_s = \int \frac{Q'}{QG} dx \int q^2 dA \tag{1}$$

which is the required general formula for shearing deflection.

3: **Special Case I.**—Constant rectangular section of height h.

For any cross section bounded by parallel sides, the unit shear at any point is given by the expression [1]

$$q = \frac{Q}{bI} \int y\, dA$$

integrated between the horizontal boundaries, where

$b =$ width of cross section
$y =$ ordinate of given point from neutral axis
$I =$ static moment of inertia of cross section with respect to neutral axis

For a rectangular section of height h this integral becomes

$$\int y\, dA = \int_y^{\frac{h}{2}} by\, dy = b\left(\frac{h^2}{8} - \frac{y^2}{2}\right)$$

and consequently

$$q = \frac{Q}{I}\left(\frac{h^2}{8} - \frac{y^2}{2}\right).$$

Substituting this value of q in the second integral of the general formula (1), it becomes for the special case under consideration

$$\int q^2 dA = \frac{Q^2}{I^2} \int_{-\frac{h}{2}}^{\frac{h}{2}} \left(\frac{h^2}{8} - \frac{y^2}{2}\right)^2 b\, dy$$

$$= \frac{144\, Q^2}{b^2 h^6} \cdot 2 \int_0^{\frac{h}{2}} \left(\frac{h^4}{64} - \frac{h^2 y^2}{8} + \frac{y^4}{4}\right) b\, dy$$

$$= \frac{6}{5} \cdot \frac{Q^2}{A}.$$

[1] Slocum and Hancock, Text-Book on the Strength of Materials, p. 57.

Hence the formula for the shearing deflection reduces in this case to the simple integral

$$D_s = \int_0^l \frac{Q'}{QG} \, dx \left[\frac{6}{5} - \frac{Q^2}{A} \right]$$

$$= \frac{6}{5} \int_0^l \frac{QQ'}{AG} \, dx. \tag{2}$$

4. EXAMPLE 1.—Determine the shearing deflection at the centre of a simple beam of constant rectangular cross section due to a single concentrated load at the centre.

Let P denote the load at centre. Then the total shear on any section is

$$Q = \frac{P}{2}$$

Also, assuming a unit load at the point whose deflection is to be determined, namely, the centre, we have

$$Q' = \frac{1}{2}.$$

Substituting these values in the above formula (2),

$$D_s = \frac{6}{5} \cdot 2 \int_0^{\frac{l}{2}} \frac{P dx}{4AG} = \frac{3Pl}{10Gbh}.$$

The relative amount of the shearing deflection as compared with the flexural deflection may be readily determined in this case. Using the same notation, the expression for the flexural or bending deflection D_B is

$$D_B = \frac{Pl^3}{4Ebh^3}$$

where E denotes Young's modulus. Now assuming the relation between the two moduli to be $G = 0.4E$, we have

$$D_s = \frac{3Pl}{4Ebh},$$

and consequently

$$\frac{D_s}{D_B} = \frac{\dfrac{3Pl}{4Ebh}}{\dfrac{Pl^3}{4Ebh^3}} = 3\left(\frac{h}{l}\right)^2$$

Hence the relative amounts of the shearing and bending deflection depends in this case on the ratio of the depth of the beam to its length. Thus

$$\text{if } h = \tfrac{1}{20} l, D_s = 0.0075\, D_B\,;$$

$$\text{if } h = \tfrac{1}{10} l, D_s = 0.03 D_B\,;$$

$$\text{if } h = \tfrac{1}{5} l, D_s = 0.12\, D_B, \text{ etc.}$$

The relative dimensions for which the shearing deflection ceases to be of importance are thus easily determined.

5. Special Case II.—Constant circular cross section of radius r.

For a circular cross section, the integral in the expression for unit shear given under Case I, namely,

$$q = \frac{Q}{bI}\int y\,dA,$$

becomes

$$\int y\,dA = 2\int_y^r \sqrt{r^2 - y^2}\; y\,dy = \frac{2}{3}\left(r^2 - y^2\right)^{\frac{3}{2}}$$

or, if the length of the chord corresponding to the ordinate y is denoted by x, then since

$$\sqrt{r^2 - y^2} = \frac{x}{2}$$

this becomes

$$\int y\,dA = \frac{2}{3}\left(r^2 - y^2\right)^{\frac{3}{2}} = \frac{x^3}{12}$$

and hence

$$q = \frac{Q}{bI} \int y\,dA = \frac{Qx^2}{3\pi r^4}$$

since

$$b = x \text{ and } I = \frac{\pi r^4}{4}.$$

Substituting this value of q in the second integral of the general formula for shearing deflection (1), we have

$$\int q^2\,dA = \int \frac{Q^2 x^4}{(3\pi r^4)^2}\, x\,dy = \frac{3^2 Q^2}{(3\pi r^4)^2} \int_{-r}^{r} \left(\frac{x}{2}\right)^5 dy$$

$$= \frac{3^2 Q^2}{(3\pi r^4)^2} \int_{-r}^{r} (r^2 - y^2)^{\frac{5}{2}}\, dy$$

$$= \frac{64 Q^2}{(3\pi r^4)^2} \int_{0}^{r} (r^2 - y^2)^{\frac{5}{2}}\, dy = \frac{10}{9}\, \frac{Q^2}{A}$$

consequently

$$D_s = \int \frac{Q'}{QG}\, dx \left[\frac{10}{9}\, \frac{Q^2}{A}\right] = \frac{10}{9} \int \frac{QQ'}{AG}\, dx. \qquad (3)$$

6. EXAMPLE. 2.—Determine the shearing deflection at the centre of a simple beam of constant circular cross section and bearing a uniform load.

Let the uniform load be of amount w pounds per unit of length. Then $Q = \frac{wl}{2} - wx$. Also assuming a unit load at the point whose deflection is to be determined, namely, the centre, we have $Q' = \frac{1}{2}$. Hence in the present case

$$D_s = \frac{10}{9} \cdot 2 \int_{0}^{\frac{l}{2}} \frac{\left(\frac{wl}{2} - wx\right)\frac{1}{2}}{AG}\, dx = \frac{5}{36} \frac{wl^2}{\pi r^2 G}.$$

The relative amount of the shearing deflection as compared with the flexural deflection is in this case given by the ratio

$$\frac{D_s}{D_B} = \frac{\dfrac{5wl^2}{36\pi r^2 G}}{\dfrac{5wl^4}{384EI}}$$

and assuming as above that $G = 0.4E$, and also denoting the depth of the beam by $h = 2r$, this becomes

$$\frac{D_s}{D_B} = \frac{5}{3}\left(\frac{h}{l}\right)^2.$$

For a circular cross section, therefore, the shearing deflection is of less relative importance for a given ratio of length to depth than for a rectangular cross section. Thus

if $h = \frac{1}{10} l$, $D_S = 0.016 D_B$ etc.

The above simple examples are given to illustrate the application of the general formula (1). The application of this formula to a beam of variable cross section is deferred to Article 12, below.

7. Derivation of General Formula for Flexural Deflection.—The ordinary method of determining flexural or bending deflection is by computing the ordinate to the elastic curve at the required point. This method has the disadvantage that each case of loading must be treated as a separate problem. A general formula, however, has been derived by Professor Fraenkel, although for some reason it does not seem to have found its way into any current texts and is therefore not generally known. The proof of this formula is usually obtained by equating the internal work of deformation to the work of the external forces. This is in fact the only proof ever seen by the writer. The Fraenkel formula, however, may be obtained from the principle of least work by applying Castigliano's theorem in precisely the same manner as applied above in deriving the general formula for shearing deflection.

For this purpose let

W_B = work of deformation due to bending
E = Young's modulus
M_1 = bending moment at any cross section
I = static moment of inertia of cross section with respect to neutral axis

Then it is well known that the work of flexural deformation for the entire beam is given by the formula [2]

$$W_B = \int \frac{M_1^2 dx}{2EI}.$$

Now in order to apply Castigliano's theorem to this expression, assume a concentrated load K applied to the beam, which is subsequently reduced to zero.

Let

M = moment at any section due to given loading
M' = moment at any section due to a *unit* load at a given point.

Then for a load K at the given point, the moment at any section due to this load may be written KM' and consequently the total moment due to the actual loading and the assumed load K becomes

$$M_1 = M + KM'.$$

Hence the above expression for the work of flexural deformation now becomes

$$W_B = \int \frac{(M + KM')^2 dx}{2EI}$$

Now by Castigliano's theorem the actual deflection due to the given loading is

$$D_B = \left[\frac{\partial W_B}{\partial K} \right]_{K = 0}$$

[2] *Ibid.*, p. 84.

and applying this to the expression for W_B, we have

$$D_B = \left[\int \frac{2(M+KM') \frac{\partial}{\partial K} (M+KM') \, dx}{2EI} \right]_{K=0}$$

or, simplifying,

$$D_B = \int \frac{MM'}{EI} \, dx \tag{4}$$

which is the required general formula for flexural deflection.

All the ordinary formulas for the flexural deflection of beams under various loadings and methods of support are simply special cases of this general formula (4), as illustrated by the following examples.

8. Example 3. —Find the flexural deflection at the centre of a simple beam of constant cross section bearing a single concentrated load P at the centre.

Here $M = \frac{Px}{2}$, and applying a unit load at the point whose deflection is desired, namely, the centre, $M' = \frac{x}{2}$. Consequently

$$D_B = 2 \int_0^{\frac{l}{2}} \frac{Px^2 dx}{4EI} = \frac{Pl^3}{48EI}.$$

9. Example 4.—Find the flexural deflection at the centre of a simple beam of constant cross section carrying a uniform load over the entire span.

In this case

$$M = \frac{wlx}{2} - \frac{wx^2}{2}, \text{ and } M' = \frac{x}{2},$$

Consequently

$$D_B = 2 \int_0^{\frac{l}{2}} \left(\frac{wlx^2}{4} - \frac{wx^3}{4} \right) \frac{dx}{EI} = \frac{5wl^4}{384EI}.$$

10. Example 5.—Find the flexural deflection at the centre of a beam of constant cross section fixed at both ends and bearing a single concentrated load at the centre.

The first step in this problem is to determine the moment at one support. This is determined from the condition that the deflection at the support is zero.

Applying a load of unity at the left support we have for sections on either side of the centre

$$\text{Left of centre} \begin{cases} M = M_0 - \dfrac{Px}{2} \\ M' = x \end{cases}$$

$$\text{Right of centre} \begin{cases} M = M_0 - \dfrac{Px}{2} + P\left(x - \dfrac{l}{2}\right) \\ M' = x \end{cases}$$

where M_0 denotes the moment at the left support. Substituting these values in the condition

$$D_B \text{ at support} = 0$$

we have

$$D_B = \frac{2}{EI}\int_0^{\frac{l}{2}}\left(M_0 - \frac{Px}{2}\right)x\,dx + \frac{2}{EI}\int_{\frac{l}{2}}^{l}\left(M_0 x + \frac{Px^2}{2} - \frac{Plx}{2}\right)dx$$

$$= \frac{2}{EI}\left[\frac{M_0 x^2}{2} - \frac{Px^3}{6}\right]_0^{\frac{l}{2}} + \frac{2}{EI}\left[\frac{M_0 x^2}{2} + \frac{Px^3}{6} - \frac{Plx^2}{4}\right]_{\frac{l}{2}}^{l} = 0$$

whence

$$M_0 = \frac{Pl}{8}.$$

Proceeding now to find the centre deflection, we have

$$M = M_0 - \frac{Px}{2} = \frac{Pl}{8} - \frac{Px}{2}$$

$$M' = \frac{l}{8} - \frac{x}{2}$$

and consequently

$$D_B = \frac{2}{EI}\int_0^{\frac{l}{2}}\left(\frac{Pl^2}{64} - \frac{Plx}{16} - \frac{Plx}{16} + \frac{Px^2}{4}\right)dx = \frac{Pl^3}{192\,EI}$$

11. EXAMPLE 6.—Find the flexural deflection at the centre of a beam of constant cross section, fixed at both ends and carrying a uniform load over the entire span.

Let

$$M_0 = \text{moment at left support}$$
$$w = \text{load in } \frac{\text{lbs.}}{\text{ft.}}$$

Then

$$M = M_0 - \frac{wlx}{2} + \frac{wx^2}{2}.$$
$$M' = x$$

To find M_0 apply the condition that the deflection at the support is zero. Then

$$D_B \text{ at left support } = \frac{1}{EI} \int_0^l \frac{\left(M_0 x - \frac{wlx^2}{2} + \frac{wx^3}{2} \right) dx}{EI}$$

$$= \frac{1}{EI} \left[\frac{M_0 x^2}{2} - \frac{wlx^3}{6} + \frac{wx^4}{8} \right]_0^l = 0$$

whence

$$M_0 = \frac{wl^2}{12}$$

To find the centre deflection we have therefore

$$M = M_0 - \frac{wlx}{2} + \frac{wx^2}{2} = \frac{wl^2}{12} - \frac{wlx}{2} + \frac{wx^2}{2}$$

$$M' = \frac{l}{8} - \frac{x}{2} \text{ (from Example 5, Art. 10)}$$

and consequently

$$D_B \text{ at centre } = \frac{2}{EI} \int_0^{\frac{l}{2}} \left(\frac{wl^3}{96} - \frac{wl^2 x}{16} + \frac{wlx^2}{16} - \frac{wl^2 x}{24} + \frac{wlx^2}{4} - \frac{wx^3}{4} \right) dx$$

$$= \frac{wl^4}{384 EI}.$$

12. VARIABLE CROSS SECTION.—The preceding examples have been given to illustrate the generality of the formulas deduced, and the method of application. By reason of their

generality, the application of the formulas may be extended to beams of variable cross section, which cannot be readily handled by ordinary methods.

The simplest law of variation is that in which the moment of inertia and cross sectional area vary linearly along the axis of the beam. This is the law which has been found to apply in the case of the planer rail considered in Article 19 below, and is probably the one which will be found to apply most generally.

Let I_0 denote the moment of inertia at the left support. Then in the case of linear variation, the moment of inertia at any variable point x is given by

$$I = I_0 + kx \qquad\qquad \left(o \overset{=}{<} x, \overset{=}{<} \frac{l}{2} \right)$$

where k is a constant depending on the form of the beam. From what precedes the total deflection due to flexure and shear is given by the expression

$$D = \int \frac{MM'}{EI}\,dx + \int \frac{Q'}{QG}dx \int q^2 dA \qquad (5)$$

The flexural deflection, given by the first term of this expression, will first be calculated.

Assume that the beam is fixed at both ends and bears a concentrated load P at the centre. Let M_0 denote the moment at the left support. To determine M_0 assume a load of unity at the left support and apply the condition that the deflection at the support is zero, as in Examples 5 and 6 above. Taking sections on either side of the centre at a distance x from the left support, we have, respectively

Left of centre
$$\begin{cases} M = M_0 - \dfrac{Px}{2} \\ M' = x \\ I = I_0 + kx \end{cases}$$

Right of centre
$$\begin{cases} M = M_0 - \dfrac{Px}{2} + P\left(x - \dfrac{l}{2} \right) \\ M' = x \\ I = I_0 + k\,(l - x) \end{cases}$$

Therefore the condition

$$D_B \text{ at support} = 0$$

becomes

$$D_B \text{ at support} = \int_0^{\frac{l}{2}} \frac{\left(M_0 - \frac{Px}{2}\right)x\,dx}{E(I_0 + kx)} + \int_{\frac{l}{2}}^{l} \frac{\left(M_0 x + \frac{Px^2}{2} - \frac{Plx}{2}\right)dx}{E(I_0 + kl - kx)} = 0$$

whence, by integration and substitution of limits,

$$M_0 = \frac{Pl}{4 \log \frac{2I_0 + kl}{2I_0}} - \frac{PI_0}{2k}.$$

To simplify the form of this expression, let

$$R \equiv \log \frac{2I_0 + kl}{2I_0}$$

and

$$H \equiv \frac{l}{4R} - \frac{I_0}{2k}$$

Then

$$M_0 = P\left(\frac{l}{4R} - \frac{I_0}{2k}\right) = PH.$$

Having determined M_0, the flexural deflection at the centre may be found by applying the unit load at this point and proceeding as above. For this purpose

$$M = M_0 - \frac{Px}{2} = P\left(H - \frac{x}{2}\right)$$

$$M' = H - \frac{x}{2}$$

and consequently

$$D_B \text{ at centre} = 2 \int_0^{\frac{l}{2}} \frac{P\left(H - \frac{x}{2}\right)^2 dx}{E(I_0 + kx)}$$

$$= \frac{2PH^2}{E} \int_0^{\frac{l}{2}} \frac{dx}{I_0 + kx} + \frac{2PH}{E} \int_0^{\frac{l}{2}} \frac{x\,dx}{I_0 + kx} + \frac{P}{2E} \int_0^{\frac{l}{2}} \frac{x^2\,dx}{I_0 + kx}$$

which, upon integration and substitution of limits, reduces to the comparatively simple form

$$D_B \text{ at centre} = \frac{Pl}{16kE} (l - 8H). \tag{6}$$

13. DISTRIBUTION OF SHEAR OVER VARIABLE SECTION.—In order to apply the general formula for shearing deflection to the case of a variable cross section, it is first necessary to determine the law of distribution of shear over the section. That is to say, it is necessary to obtain a formula for a variable section corresponding to the formula

$$q = \frac{Q}{bI} \int y\,dA$$

for a constant cross section, as used in Articles 3 and 5 above. For this purpose, proceed as follows:

The ordinary formula for bending stress at any point in a beam is

$$p = \frac{My}{I}$$

Now differentiate this expression with respect to x, remembering that both I and M are functions of x. Then

$$\frac{dp}{dx} = \frac{\dfrac{dM}{dx} yI - \dfrac{dI}{dx} My}{I^2}$$

or, since

$$\frac{dM}{dx} = Q \text{ and } \frac{dI}{dx} = k,$$

this becomes

$$\frac{dp}{dx} = \frac{Qy}{I} - \frac{kMy}{I^2}$$

Now let z denote the width of the cross section at any point, and q the unit shear acting over the area $z\,dx$ (Fig. 1). Since

this equilibrates the difference in normal stress on adjacent sections, we have

$$\int dp \, dA = qz \, dx$$

Therefore, eliminating dp between this equation and the one preceding, we have

$$\int \left(\frac{Qy}{I} - \frac{kMy}{I^2} \right) dA = qz$$

whence

$$q = \frac{QI - kM}{zI^2} \int y dA \tag{7}$$

which is the required law of distribution of shear.

For a constant cross section, $k = o$ and $z = $ constant, say b, in which case equation (7) reduces to

$$q = \frac{Q}{bI} \int y dA$$

as in Articles 3 and 5 above.

Fig. 1.
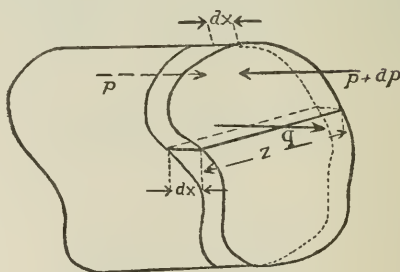
In Article 3 it was found that the second integral in the general formula became for the case there considered

$$\int q^2 dA = \frac{6}{5} \frac{Q^2}{A} = 1.2 \frac{Q^2}{A}$$

and in Article 5 it became

$$\int q^2 dA = \frac{10}{9} \frac{Q^2}{A} = 1.11 \frac{Q^2}{A}.$$

The corresponding expressions for values of q given by equation (7) will now be evaluated for four different forms of variable cross section.

14. VARIABLE RECTANGULAR SECTION.—
For a rectangular cross section

$$\int y dA = z\left(\frac{h^2}{8} - \frac{y^2}{2}\right)$$

and consequently

$$q = \frac{QI - kM}{I^2}\left(\frac{h^2}{8} - \frac{y^2}{2}\right).$$

Hence

$$\int q^2 dA = \frac{(QI - KM)^2}{I^4} \int_{-\frac{h}{2}}^{\frac{h}{2}} \left(\frac{h^2}{8} - \frac{y^2}{2}\right) z dy$$

$$= \frac{6}{5} \frac{(QI - kM)^2}{I^2 A} \tag{8}$$

15. VARIABLE CIRCULAR SECTION.—
For a circular cross section

$$\int y dA = \frac{2}{3}\left(r^2 - y^2\right)^{\frac{3}{2}} = \frac{z^3}{12}$$

Hence

$$q = \frac{QI - kM}{I^2} \cdot \frac{z^2}{12}$$

and consequently

$$\int q^2 dA = \frac{(QI - kM)^2}{144 I^4} \int z^4 dA = \frac{64(QI - kM)^2}{144 I^4} \int_0^r (r^2 - y^2)^{\frac{5}{2}} dy$$

$$= \frac{10}{9}\frac{(QI - kM)^2}{I^2 A} \tag{9}$$

It is evident from the similarity of these expressions with those previously deduced that the integral

$$\int q^2 dA$$

is some constant multiple of the quantity

$$\frac{(QI - kM)^2}{I^2A}.$$

It therefore becomes important to determine the range of values of this constant for typical forms of cross section.

16. Hollow Rectangle or **I**.—

For this purpose consider first a hollow rectangle or **I** of

Fig. 2.
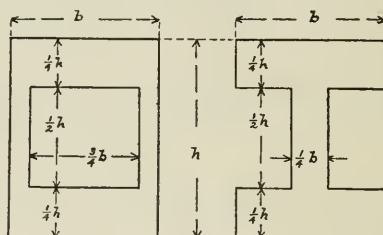
the relative dimensions shown in Fig. 2. In this case for y between $\frac{h}{4}$ and $\frac{h}{2}$ we have

$$\int ydA = \int_{y\left(>\frac{h}{4}\right)}^{\frac{h}{2}} zydy + \int_{y\left(<\frac{h}{4}\right)}^{\frac{h}{4}} z'ydy = b\left(\frac{h^2}{8} - \frac{y^2}{2}\right)$$

whereas for y between 0 and $\frac{h}{4}$,

$$\int ydA = \int_{\frac{h}{4}}^{\frac{h}{2}} zydy + \int_{y}^{\frac{h}{4}} z'ydy = b\left(\frac{13h^2}{128} - \frac{y^2}{8}\right)$$

Consequently, for $\frac{h}{4} < y < \frac{h}{2}$ we have

$$q = \frac{QI - kM}{I^2}\left(\frac{h^2}{8} - \frac{y^2}{2}\right)$$

and for $0 < y < \frac{h}{4}$ we have $\left(\text{since } z = \frac{b}{4}\right)$

$$q = \frac{QI - kM}{I^2}\left(\frac{13}{32}h^2 - \frac{y^2}{2}\right)$$

Substituting these values of q in the integral

$$\int q^2 dA,$$

and integrating between the given limits we have therefore

$$\int q^2 dA = \frac{(QI - kM)^2}{I^4}\left[\int_{\frac{h}{4}}^{\frac{h}{2}} 2\left(\frac{h^2}{8} - \frac{y^2}{2}\right)^2 bdy + \int_0^{\frac{h}{4}} \frac{1}{2}\left(\frac{13}{32}h^2 - \frac{y^2}{2}\right)bdy\right]$$

$$= \frac{(QI - kM)^2 bh^5}{I^4} \cdot \frac{262}{12288} .$$

In the present case, however, it is found that $I = \frac{29}{384}bh^3$ and $A = \frac{5}{8}bh$, and consequently the above expression reduces to

$$\int q^2 dA = \frac{(QI - kM)^2 bh^5}{I^2\left(\frac{29}{384}\right)^2 b^2 h^6} \cdot \frac{262}{12288}$$

$$= 2.099 \frac{(QI - kM)^2}{I^2 A} . \tag{10}$$

Now let the relative dimensions of the rectangle or **I** be

altered to those shown in Fig. 3. Then proceeding as above we have for

$$\frac{3h}{8} < y < \frac{h}{2}$$

$$\int y dA = \int_y^{\frac{h}{2}} zy dy = b\left(\frac{h^2}{8} - \frac{y^2}{2}\right)$$

and for $0 < y < \frac{3h}{8}$

$$\int y dA = \int_{\frac{3h}{8}}^{\frac{h}{2}} zy dy + \int_y^{\frac{3h}{8}} z' y dy = \frac{37}{512}bh^2 - \frac{by^2}{8}$$

FIG. 3.
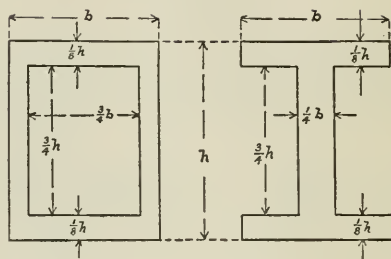
Hence the corresponding values of q are

$$q = \frac{QI - kM}{I^2}\left(\frac{h^2}{8} - \frac{y^2}{2}\right) \qquad\qquad \frac{3h}{8} < y < \frac{h}{2}$$

and

$$q = \frac{QI - kM}{I^2}\left(\frac{37h^2}{128} - \frac{y^2}{2}\right) \qquad\qquad 0 < y < \frac{3h}{8}.$$

The integral in question becomes therefore

$$\int q^2 dA = \frac{(QI - kM)^2}{I^4}\left[2\int_{\frac{3h}{8}}^{\frac{h}{2}}\left(\frac{h^2}{8} - \frac{y^2}{2}\right)^2 b dy + \frac{1}{2}\int_0^{\frac{3h}{8}}\left(\frac{37h^2}{128} - \frac{y^2}{2}\right)^2 b dy\right]$$

$$= \frac{(QI - kM)^2}{I^4} bh^5 \cdot \frac{13349}{983040}$$

or, since in this case $A = \frac{7}{16} bh$ and $I = \frac{175bh^3}{3072}$, this becomes

$$\int q^2 dA = 1.83 \frac{(QI - kM)^2}{I^2 A} \qquad (11)$$

17. GENERAL FORMULA FOR SHEARING DEFLECTION, VARI-ABLE CROSS SECTION.—It is evident, therefore, that for any ordinary form of cross section the constant which multiplies the expression $\frac{(QI - kM)^2}{I^2 A}$ lies between 1 and 2. Let this constant be denoted by n. Then the general formula for the shearing deflection of a beam of variable cross section may be written

$$D_s = n \int \frac{Q'}{QG} \frac{(QI - kM)^2}{I^2 A} \, dx. \qquad (12)$$

If $k = 0$, i.e., the cross section is constant, this reduces to the special form used in Articles 3 and 5.

18. APPLICATION.—Now consider the special application of the result just obtained to a beam of variable cross section, fixed at both ends, and carrying a single concentrated load at the centre. Assume, moreover, that the moment of inertia and the cross sectional area both vary linearly. Then we have

$$I = I_0 + kx \qquad\qquad Q = \frac{P}{2}$$
$$A = A_0 + cx$$
$$M_0 = PH \qquad\qquad Q' = \frac{1}{2}$$

Substituting these values in the expression for the shearing deflection D_s, given by equation (12), we have

$$D_s \text{ at centre} = \frac{2Pn}{G} \int_0^{\frac{l}{2}} \left[\frac{1}{4(A_0 + cx)} - \frac{k\left(H - \frac{x}{2}\right)}{(I_0 + kx)(A_0 + cx)} \right.$$

$$\left. + \frac{k^2\left(H - \frac{x}{2}\right)^2}{(I_0 + kx)^2 (A_0 + cx)} \right] dx$$

which by integration and reduction finally becomes

$$D_s \text{ at centre} = \frac{Pn}{2Gc} \left\{ \frac{ckl(I_0 + 2kH)^2}{I_0(kA_0 - cI_0)(2I_0 + kl)} + 4 \log \frac{2I_0 + kl}{2I_0} \right.$$

$$\left. - \left[1 + \frac{k(2cH + A_0)}{A_0 k - cI_0} \right]^2 \log \frac{A_0(2I_0 + kl)}{I_0(2A_0 + cl)} \right\} \qquad (13)$$

19. NUMERICAL APPLICATION TO PLANER RAIL.—As a numerical application of formulas (6), Article 12, and (13), Article 18, consider the deflection of the rail of a standard planer, the one here used for illustration being that shown in Fig. 4. The distance between supports is in this case $l = 35\frac{1}{2}$. This distance was divided up into 8 equal parts and a cross section of the rail plotted to scale at each point of division, these cross sections being thus 4.44 inches apart. In this way it was found that the moment of inertia varied linearly to a close approximation, *i.e.*, $I = I_0 + kx$ where in the present case $I_0 = 45$ and $k = 20$. It was also found that the area followed approximately the straight line law, *i.e.*, $A = A_0 + cx$, where $A_0 = 25$ and $c = 1.4$.

Now for purposes of computation, assume a unit load of 1000 pounds on the point of the tool. Then the flexural and shearing deflections are obtained by substituting the following numerical quantities in formulas (6) and (13).

$P = 1000$ lbs. $\qquad\qquad$ $A_0 = 25$ in.^{2}

$n = 1.8$ $\qquad\qquad\qquad$ $c = 1.4$ in.

$E = 15,000,000 \frac{\text{lbs.}}{\text{in.}^2}$ $\qquad$ $l = 35.5$ in.

$\qquad\qquad\qquad\qquad\qquad$ $R = \log_e \frac{2I_0 + kl}{2I_0} = 2.184802$

$G = 6,000,000 \frac{\text{lbs.}}{\text{in.}^2}$

$I_0 = 45$ in.^{4} $\qquad\qquad$ $H = \frac{l}{4R} - \frac{I_0}{2k} = 2.93715$

$k = 20$ in.^{3}

Hence from formula (6), Article 12, the flexural deflection at the load is found to be

$$D_B = 0.00008877 \text{ in.}$$

and similarly, from formula (13), Article 18, the shearing deflection at the load is found to be

$$D_s = 0.00009766 \text{ in.}$$

It is noteworthy that the shearing deflection is found to be in excess of the flexural deflection. This is due partly to the fact

that, for any beam, as the ratio of depth to length increases the ratio of shearing to flexural deflection also increases, as shown in Articles 4 and 6, but more especially in the present case to the fact that the rail is designed entirely for flexural rigidity, the material being concentrated where the moment is greatest, without reference to the shear, which is constant throughout.

For the planer rail here considered, the load on the point of the tool also produces a torsional strain in addition to shear and

FIG. 4.
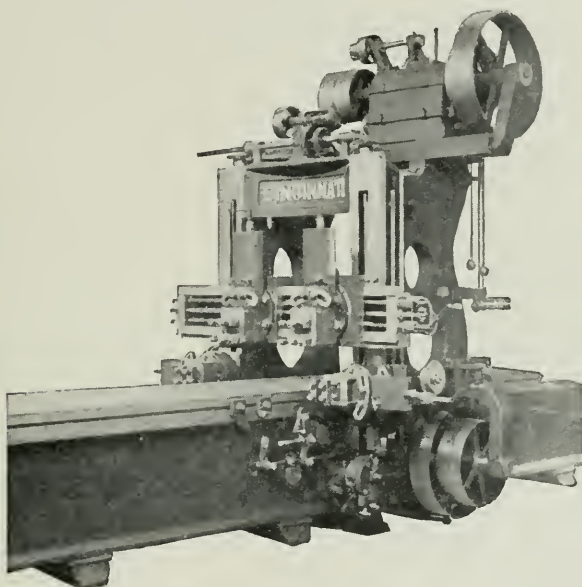
flexure, the amount of the torque being equal to the load on the tool multiplied by its eccentricity, or distance from the point of the tool to the centre of gravity of the rail. To calculate this torsional deflection, St. Venant's general formula will be used, namely,

$$\theta = \frac{4\pi^2 T I_p}{G A^4} \tag{14}$$

where

$\theta =$ angle of twist per unit of length in radius
$T =$ torque in inch-pounds
$I_p =$ polar moment of inertia of cross section in biquadratic inches.

Assuming the distance from the point of the tool to the centre of gravity of the rail to be 12 inches for the rail here considered, the torque corresponding to a unit load of 1000 pounds is 12,000 inch-pounds. Since both ends of the rail are fixed and the torque applied at the centre, the torsional strain may be computed by taking half the rail and considering it fixed at one end and subjected to a torque of 6000 inch-pounds at the other. Since the rail is of variable section, the angle of twist is computed separately for each of the four segments into which each half of the rail is divided by the given cross sections, using the average polar moment of inertia and average area of cross section for each portion. Each angle of twist for unit length is then multiplied by the length of the segment, namely, 4.44 inches, and the results added for the total angular deflection. The results of this computation are summarized in the following table.

Polar moment of inertia, I_p	Average, I_p	Area, A	Average, A	Angle of twist in radians
563.28 }.......	688.43	24.42 }......	28.69	$.0001781$
813.59 }.......	882.05	32.97 }......	35.26	$.0001000$
950.51 }.......	1020.19	37.56 }......	38.44	$.0000818$
1089.87 }.......	1333.18	39.32 }......	55.17	$.0000252$
1576.50		71.02		
Total angular deflection.............................				$.0003851$

The deflection at the point of the tool due to torsional strain is obtained by multiplying this angular deflection by the eccentricity, viz., 12 inches, i.e.,

Torsional deflection $= 12 \times 0.0003851 = 0.0046212$ inch.

Combining the preceding results, the total horizontal deflection at the point of the tool, due to combined flexure, shear, and torsion, is found to be for a unit load of 1000 pounds

$$\text{Total horizontal deflection} = 0.00008877 + 0.00009766 + 0.0046212$$
$$= 0.00480763 \text{ inch.}$$

From formulas 6, 13, and 14 above, it is evident that in each case the deflection is proportional to the load on the tool. Hence the actual deflection under any given load may be found from the above by means of a simple proportion. To find the load on the tool, the best data available are those obtained by Taylor from his experiments on cutting metals. These experiments show that the load on the tool depends primarily on the cross section of chip removed, which for cast-iron has been found to be about 99 tons (2000 pounds) per square inch of cross section of chip. Assuming a maximum cut of $\frac{1}{8} \times \frac{3}{8}$ inch for the planer here considered, the load on the tool is $\frac{3}{64} \times 99 \times 2000 = 9280$ pounds, and the corresponding deflection $= 9.28 \times 0.0048 = 0.0445$ inch.

For a finishing cut the deflection is of course much less. Thus for a cut of $\frac{1}{64}$ inch with the same tool the load would be $\frac{1}{64} \times \frac{3}{8} \times 99 \times 2000 = 1160$ pounds and the corresponding deflection $= 0.005568$ inch.

It is also to be noted that the deflection computed above is horizontal, and hence, as a rule, does not affect the accuracy of operation of the machine. The vertical deflection is the vertical component of the rotation due to torsional strain. Thus if a denotes the angle of torsion under the assumed unit load of 1000 pounds, we have from the results tabulated above

$$\text{tangent } a = 0.0003851$$

and consequently

$$\text{Vertical deflection} = 12\ (1 - \cos\ a) = 0.0000084 \text{ inch.}$$

For the maximum load of 9280 pounds corresponding to a cut of $\frac{1}{8} \times \frac{3}{8}$ inch, this becomes

$$\text{Maximum vertical deflection} = 0.00007795 \text{ inch.}$$

As this quantity is so small, the machine may be considered as perfectly rigid for all practical purposes.

Cast-Iron in Piston Rings. H. M. LANE. (*Trans. Amer. Foundryman's Assocn.*, xix, 201.)—As a piston ring is a spring it should not contain less than 0.65 per cent. carbon and may be considered as a steel spring containing silicon, sulphur, phosphorus, manganese, and graphitic carbon. The graphite gives wearing qualities while the combined carbon gives the elasticity, and phosphorus hardness. Piston rings should be cast so as to require very little machining. It is concluded that any given composition of the metal has a certain most efficient thickness; *i e.,* if the castings are made thinner the metal will be chilled and the machine cost will rise, and if the casting be made thicker, the grain will be more open and the strength rapidly reduced. There should be coöperation between the designer, the foundry and the machine shop.

Available Water-Power of Sweden. T. KOEHN. (*Elektrotech. Zeit.,* xxxi, 1189.)—This deals with the hydro-electric installation already erected by the State, that of Trollhätten, which has now a capacity of 40,000 h. p. while funds for its enlargement to 80,000 h. p. have been voted. A Second Station is to be built in northern Sweden, near Porjus, to be 37,500 h. p. at first, but later to be increased to 100,000 h. p. and to be completed in 1914. A third station of 40,000 h. p. is to be built at Dabälpen, about 130 miles north of Stockholm. Other projects are mentioned and a map shows the position and size of the stations already erected or in course of construction.

Unattended Fog Signal and Lighthouse at Guernsey. ANON. (*Engineer,* cix, 360.)—All the operations are electrically controlled from the mainland by means of an armored multi-cove cable. The cost of the whole work will reach $40,000 as compared with $300,-000 which an ordinary lighthouse would cost. Only two keepers will be needed on the mainland in place of four which an isolated lighthouse would require.

Comparison of Aluminum and Copper for Underground Cables. F. C. RAPHAEL AND J. B. SPARKS. (*Elect. Eng.,* vi, 749.)—At present prices aluminum cables are cheaper than copper, whether armored or unarmored. No kind of solder can be recommended for joining aluminum cables, but the skin resistance of the film of oxide is very small, and a method of clamping the ends together under considerable pressure, has given good results for house connections. A 'cast weld joint has been successful for joining large cables. Sweated terminals have been used, each strand of the cable being tinned with special solder. The cost of laying is another matter, and might be greater for aluminum in certain sizes.

NEW METALLIC FILAMENT LAMPS.

BY

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In speaking to you this evening, on the subject of new metallic filament lamps, I wish to deal particularly with the lamps themselves, rather than with their almost endless applications in commercial service.

Although there are several essential parts of an incandescent lamp, the most important part is the light-giving filament. It is rather striking to compare the relatively insignificant bulk of the filament material with the area which it ordinarily illumin-

FIG. 1.
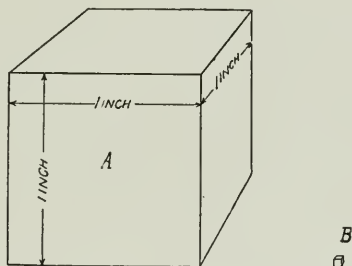
B Represents Amount of Filament Material in a
60watt 110 Volt Mazda Lamp.

ates. A 60-watt tungsten filament lamp will illuminate very satisfactorily a fairly large room, yet, its filament, if crushed to powder would make a cube of less than one-twentieth of an inch on each side (Fig. 1). Few substances are put to such severe treatment as the bit of matter which composes the filament of an incandescent lamp and the number of materials which can be used for this purpose is consequently very limited.

A study of the necessary physical properties of filament materials in general is interesting and may serve to indicate how

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* Presented at the meeting of the Electrical Section held Thursday, January 12, 1911.

difficult it is to secure materials which will meet satisfactorily the several requirements. Before giving any consideration to the physical characteristics, however, we must assume that the material can be put in the form of slender threads, uniform in structure and diameter, for otherwise its use as a filament is precluded.

The physical properties of materials which are of importance in filament study are:

1. Electrical resistance.
2. Vapor tension and melting point.
3. Emissivity.
4. Selectivity.
5. Mechanical strength.

Perhaps the most important physical requisite of a filament material is that it should be a simple electric conductor. It should not only be a good conductor when cold, but it should not become electrolytic when heated as do some metallic oxides. These characteristics are necessary in order to make it possible to operate the lamps on commercial multiple circuits without resort to auxiliary devices and further to make it possible to operate the filaments in a vacuum and thus increase the luminous efficiencies by reducing the loss of heat from the filament. Perhaps it is not generally recognized that the vacuum is an extremely important factor in establishing the value of the luminous efficiency of incandescent filament lamps in general. An example may make this clear.

A tungsten filament which would have required 9.8 watts to maintain it at its normal working temperature in a vacuum, required 63.9 watts or about six and a half times as much power to maintain it at the same temperature (as judged by the resistance) when in a non-oxidizing atmosphere.[1] It is thus apparent that the loss of heat from a filament would greatly reduce the efficiency of light production if the filament were operated in anything but a vacuum.

The filament, being essentially an electric conductor, should have certain electrical characteristics. It is desirable that the

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[1] The gas used in this particular case contained quite a little hydrogen and since hydrogen is an exceptionally good medium for heat conduction if the atmosphere had contained no hydrogen, the loss would have been somewhat smaller.

specific resistance of the filament at the working temperature should be rather high in order to make it possible to use comparatively short filaments of considerable diameter in lamps of the candlepowers and voltages which have become standard in the lighting industry. As the specific resistance of carbon is much greater than that of the metals commonly used as filaments, the metal filaments must be much finer and longer to produce lamps comparable with the carbon lamps in wattage and voltage. As a consequence of this difference new types of lamp construction have been developed for the metal filament lamps, some of which are rather elaborate especially in the 200- to 250-volt types where from four to five feet of filament must be disposed of within a comparatively small bulb. The loss of heat from the filament through conduction by the supporting hooks and wires in the case of the tantalum type construction, where the filament is supported at about 23 points, has been shown by Dr. Hyde to be about 7 per cent.

It is desirable that the filaments possess a high positive temperature resistance coefficient since the greater the value of the coefficient, the less the changes in current, wattage and candlepower with fluctuations in applied voltage.

One per cent. increase in voltage will give approximately the following percentage increase in current in lamps of different kinds :

Tungsten	0.59 per cent.
Tantalum	0.72 per cent.
Metallized carbon	0.77 per cent.
Treated carbon	1.07 per cent.
Untreated carbon	1.31 per cent.

If the resistance temperature coefficient were zero (*i.e.*, if the resistance did not change at all with the temperature), the percentage change in current would correspond exactly to the percentage change in voltage. A positive value of the temperature coefficient gives a smaller percentage change in current than in voltage, while a negative temperature coefficient gives a greater percentage change in current than in voltage.

The relative change in wattage and candlepower with voltage differs greatly in lamps with various filament materials, due, probably, in part, to the difference in the resistance temperature coefficients.

One per cent. increase in voltage of a lamp operating at normal efficiency and having filaments of

	Increases wattage.	Increases c. p.
Tungsten	1.59 per cent.	3.73 per cent.
Tantalum	1.72 per cent.	4.27 per cent.
Metallized carbon	1.77 per cent.	4.90 per cent.
Treated carbon	2.07 per cent.	5.69 per cent.
Untreated carbon	2.32 per cent.	7.10 per cent.

These figures would apply only to a change in voltage which takes place rather slowly, *i.e.,* slowly enough to allow for the lag in the filament temperature. When the applied voltage changes with greater rapidity, as in operation on alternating current,

Fig. 2.
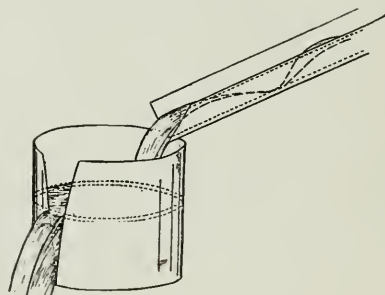
the thermal capacity of the filament tends to equalize to a greater or less extent the fluctuations in the filament temperature.

The manner in which the thermal capacity of a filament tends to reduce the fluctuation in temperature (when operating. on alternating power supply) may be illustrated by the hydraulic analog of a special reservoir into which water flows at a variable rate. The water put into the reservoir corresponds to the electrical energy put into the filament. The reservoir, we will assume, has a slit in the side through which the water escapes (Fig. 2). The water flowing out represents the energy dissipated from the filament by radiation, conduction and connection. Although the rate of inflow may vary over a wide range, the level of the water in the reservoir fluctuates but very little and the rate of outflow remains nearly uniform. The greater the diameter of the reservoir, compared with the rate of inflow, and

the greater the frequency of the pulsating supply, the less the fluctuation in water level and in outflow. The diameter of the reservoir corresponds to the thermal capacity of the filament and the fluctuation of water level represents fluctuation in filament temperature. In the case of the filament, the greater the thermal capacity and the greater the frequency of the alternating power supply, the less will be the fluctuation in temperature and in candlepower throughout each cycle.

In the case of tungsten filament lamps, the cold resistance is only about one-eleventh of the resistance at the temperature of normal operation. These lamps therefore take a momentary starting current above that of normal operation, when thrown onto multiple circuit. The effect of this momentary starting current is extremely small and it is not necessary to discuss it further than to mention its existence.

The filament of an incandescent lamp must not only meet certain requirements of an electric conductor but it must also possess certain characteristics as a luminous radiator. The latter condition greatly limits the number of materials which can be used as filaments of incandescent lamps. The light of incandescent lamps is produced by temperature radiation as distinguished from luminescence or florescence. It is therefore desirable to operate the incandescent filament at as high a temperature as possible in order that the proportion of the energy radiated within the visible spectrum and hence the efficiency of light production may be high.

The maximum temperature at which it is possible to commercially operate a certain material in the high vacuum of an incandescent lamp bulb is determined by its rate of disintegration if the vapor tension is high and by its melting point if the vapor tenson is low. The high vapor tension of the carbon filament which is shown by its tendency to evaporate at temperatures far below its melting point makes it impossible to commercially operate carbon filaments at the normal working temperature of the tungsten filament. Obviously any filament can be operated for a short time at a temperature and efficiency far above that at which it gives a reasonable commercial life, but such a gain in efficiency is secured only by the sacrifice of the lamp itself. On the other hand, operation at a low temperature requires a correspondingly greater consumption of energy for the light pro-

duced, and this cannot be compensated for by the decreased rate of depreciation of the filament. The efficiencies at which the various filaments should operate in commercial service have been determined by a consideration of the economy of light production, and lamps are rated at voltages corresponding as nearly as possible to such efficiencies.

Not only do the various filament materials differ in their ability to withstand high operating temperatures but they differ also in their radiating properties. The amount of energy which can be radiated from equal surfaces of different materials at the same temperature is found to vary considerably. The emissivity or mere ability to radiate energy does not affect the luminous efficiency but it plays an important part in determining the lengths and diameters of filaments in the commercial lamps.

The study of the radiating properties of various materials leads eventually to a consideration of their ability to radiate relatively different quantities of energy in certain portions of the spectrum when at the same true temperature. When a material tends to radiate relatively more energy in the visible spectrum than other bodies at the same temperature an important means of securing high luminous efficiency is offered through its use.

To show to what an extent such selective radiation may assist in attaining high efficiencies, reference may be made to the paper by Dr. Hyde presented before this Society last March.[2] The data given by Dr. Hyde show that when filaments of various materials are operated at temperatures which give a color match with an untreated carbon filament, the relative efficiency of light production varies over a considerable range, depending both upon the radiating material and upon the temperature of the untreated filament with which a color match is made.

Without going into further detail the data may be presented in the form of curves in Figure 3 simply to emphasize the differences which exist between various substances, as luminous radiators. If the materials could be compared at the same true temperatures instead of at the temperatures at which they gave the same color match the gain in efficiency due to selective radia-

[2] " The Physical Production of Light," by Edward P. Hyde, Journal of the Franklin Institute, July, 1910.

tion would, in all probability be more pronounced.[3]   Dr. Hyde concludes that the metal osmium would be possibly at least 40 or 50 per cent. more efficient as a luminous radiator than the untreated carbon.   A consideration of the curves would indicate a similar possible gain in efficiency of from 25 to 30 per cent. in the case of tungsten and from 10 to 15 per cent. in the case of tatalum.

Selectivity and emissivity are often confused and effects at least partly due to low emissivity are sometimes ascribed to selectivity.   One writer [4] has recently attempted to show the selectivity of tungsten with respect to carbon by calling attention to the

FIG. 3.
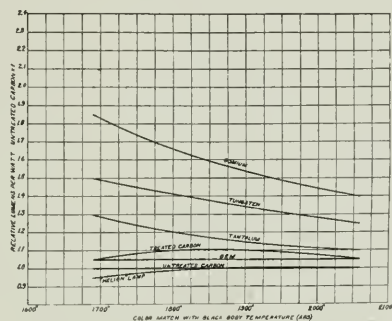
Relative lumens per watt at color match.
(Data from paper by Dr. E. P. Hyde.)

fact that when operating at the same luminous efficiency, the carbon filament shows a smaller surface area per candle than the tungsten.   He concludes that the carbon filament must therefore be at a higher temperature than the tungsten to give the same luminous efficiency and that the latter must evidently be a selective radiator.   While his conclusion is fortunately correct, the method of demonstration is not rigorous, for the difference in surface per candle at the same luminous efficiency need

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[3] In connection with this subject, I may further refer to the paper on the "Reflecting Power of Various Metals," by W. W. Coblentz (Journal of the Franklin Institute, September, 1910).   A number of materials show properties of selective reflection which indicate that they would make efficient luminous radiators.

[4] Hartwig von Löte, Lecture before the Elektrotechniche Verein in Vienna.

not indicate a difference in temperature due to the fact that the emissivity of the two filaments may be different.

For example, we might have two filaments of exactly the same length and diameter, having the same relative distribution of energy throughout the entire spectrum when at the same temperature, but differing in emissivity so that the total energy radiated by the one would be but one-third of that radiated by the other. When at the same temperature these two filaments might have energy distribution curves, as shown in Fig. 4. Now since the two bodies are assumed to have the same distribution of energy, their efficiencies of light production as measured by the ratio of energy radiated in the visible spectrum, to the total energy radiated must be the same. However, due entirely to its lower emissivity, the filament of the one material (*B*) would

FIG. 4.

RADIATION FROM BODIES OF DIFFERENT EMISSIVITY

CURVE A $= \phi(\mu)$ CURVE B $= K \phi(\mu)$

$$\text{EFFICIENCY-}A = \frac{\text{AREA } acdf}{\text{AREA UNDER CURVE } A} = \text{EFFICIENCY-}B = \frac{\text{AREA } abef}{\text{AREA UNDER CURVE } B}$$
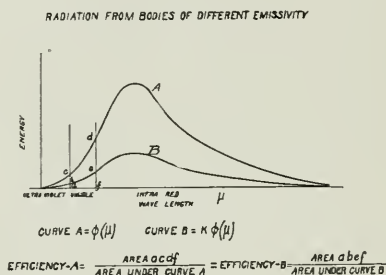
give just one-third the candlepower of the filament of the material (*A*) possessing a higher emissivity. In this case the temperatures are identical, and in spite of the fact that the surface area per candle differs greatly, there is no selectivity since we assumed to begin with that the distribution of energy throughout the spectrum was the same for each material. Consequently the assumption that the surface area per candlepower indicates a selectivity is unwarranted, for it is quite conceivable that a material could have such a low emissivity as to give even a greater area per candle than tungsten when measured at the same luminous efficiency and still be far less selective.

The metal osmium has been shown to possess the property of selective radiation in the visible spectrum to a high degree, but the difficulty of working it and its relatively low melting point have made its commercial use impracticable. Tungsten, while

not quite as selective as osmium, is more plentiful, and more-over it can be operated commercially at a higher temperature and efficiency so that it is a more desirable filament material than osmium in spite of the greater selectivity of the latter sub-stance. Investigation as to selectivity of various substances is constantly being carried on and the future may reveal materials which meet the severe requirements imposed on incandescent filaments in general, which are even more selective than those known to-day.

A comparison of length and diameter of filaments of various kinds, which would be required to produce lamps of identically the same candlepower and voltage at the same luminous effi-ciency, may serve to illustrate concretely the manner in which

FIG. 5.
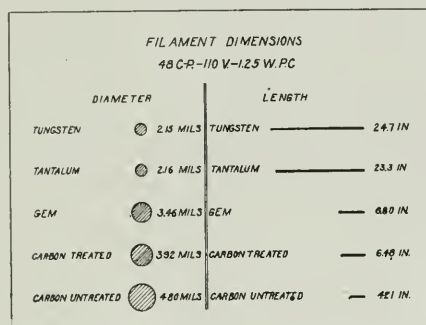
variations in the specific resistance and in the radiating properties of various materials will effect the filament dimensions.

In order to produce lamps of 48 candlepower, 110 volts, 1.25 w.p.c., the filament dimensions would be approximately as shown in Fig. 5. The difference in the lengths of the metal filament and the carbon filaments is seen to be particularly great.

The foregoing discussion may indicate some of the physical properties of a material which are of importance in determining its suitability for use as an incandescent filament. It is, how-ever, one thing to determine what materials would theoretically make good filaments—judged from the several stand-points pre-viously mentioned, but it is quite another matter to commercially produce filaments of the chosen materials. The greatest problem in the production of metallic filament incandescent lamps has been to produce the filament material in a high state of purity and in

the proper physical form, and the ingenuity of the manufacturer
has been taxed to the utmost in devising means by which this can

FIG. 6.
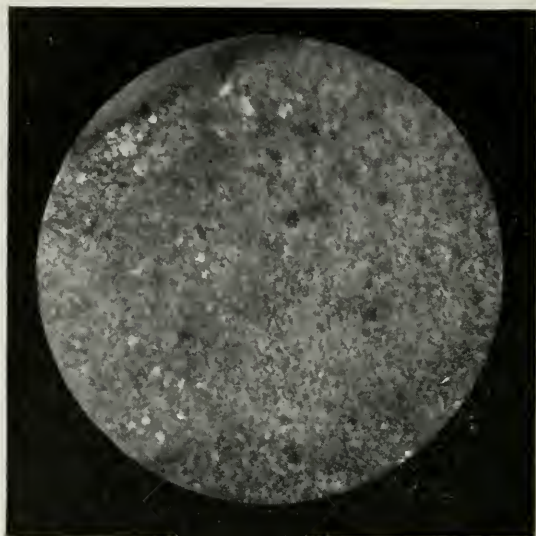
be accomplished.[5]   Incidentally it might be mentioned that largely
through the continued effort of various investigators to produce

[5] The general equations by which the length and diameter of a filament of
any given material, voltage, candlepower and efficiency can be calculated (pro-
vided that certain constants are obtained from a sample filament) are
expressed below :

FILAMENT EQUATIONS.

$d =$ Diameter of filament.
$l =$ Length of filament.
$R =$ Resistance of filament 1 mm. in diameter.
        1 mm. in length at operating temperature.
$S =$ Surface per watt.
$V =$ Volts.
$e =$ Watts per candle.
$cp. =$ Candlepower.

$$S = K_1 e^b \qquad\qquad R = K_2 e^a$$

$$d = K_1^{\frac{1}{3}} K_2^{\frac{1}{3}} e^{\frac{a+b+2}{3}} \pi^{-\frac{1}{3}} V^{-\frac{2}{3}} (cp.)^{\frac{2}{3}}$$

$$l = K_1^{\frac{2}{3}} K_2^{-\frac{1}{3}} e^{\frac{-a+2b+1}{3}} \pi^{-\frac{2}{3}} V^{\frac{2}{3}} (cp.)^{\frac{1}{3}}$$

filaments of refractory materials, the general knowledge of the metallurgy and chemistry of such metals as osmium, tungsten, molybdenum and tantalum has been advanced wonderfully within the last few years.

Tungsten filaments from 0.001 to .013 inch in diameter are required in lamps at present on the market. Filaments as small as 0.0008 inch can be made commercially and in an experimental way, filaments as small as 0.00068 inch have been produced. The latter filament is small enough to make a lamp of about 8 or 9 candlepower at 110 volts and at 1.25 w.p.c.

Fig. 7.
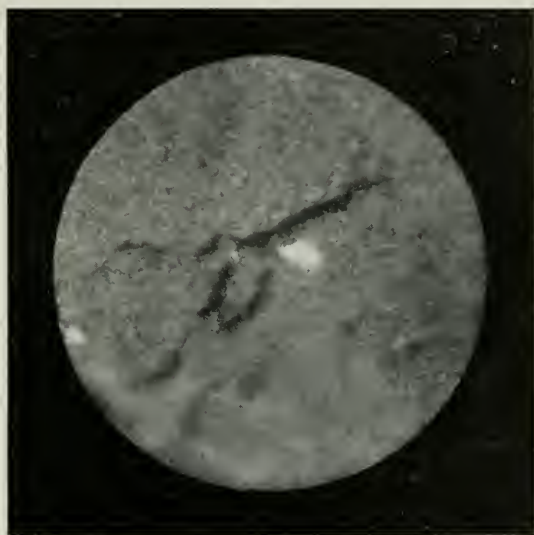
The mechanical difficulty of manufacturing such small filaments to exact and uniform dimensions is not the only one encountered in their production. The filaments must be of a uniformly high degree of purity, in order that the lamps will give good commercial service. It is difficult to secure a high degree of purity in tungsten metal, principally because its atomic weight is high and in consequence thereof a very little carbon (which is the most common impurity) is sufficient to form a considerable amount of tungsten carbide (probably W_2C), a compound which has altogether different physical properties than the metal itself. Tungsten carbide (W_2C) contains only 3.16

per cent. carbon by weight; 1 per cent. of carbon in tungsten metal would give about 31.6 per cent. of this tungsten carbide and would render the metal only 69.4 per cent. pure. Tungsten as it exists in the finished filaments of present commercial lamps probably contains less than 0.01 per cent. of combined carbon. The difficulties encountered in refining tungsten are very great, and it is only by the use of the greatest precautions that metal as pure as that required in commercial filaments can be secured. From this it may be seen that the amount of material actually contained in the filament of an ordinary tungsten lamp can give

Fig. 8.

no adequate idea of the value of the filament as it exists in the slender thread of highest purity.

The examination of the filament of an incandescent lamp under the microscope reveals many interesting changes during the various processes of manufacture and during the subsequent burning. This applies particularly to the metal filaments.

The structure of the tungsten filaments may be best shown by microphotographs of the cross-sectional fracture. It is very difficult to get micrographs which will show distinctly this structure, due to the fact that all parts of the slightly irregular surface cannot be brought into sharp focus. In looking at the specimens under the microscope, where the focus can be gradually changed, the character of the surface can be seen to much

better advantage. For the purpose of illustrating the change in structure during one process of manufacture, micrographs of rather heavy filaments have been prepared since the large filaments show the change to somewhat better advantage. The filaments represented in the micrographs are about 0.008 inch in diameter, practically six times the diameter of a 40-watt 110-volt filament. The first micrograph (Fig. 6) illustrates the filament as pressed from a mixture of very finely divided metallic tungsten and a binding material. It has a dull black fracture which exhibits an extremely fine structure. Little visible change takes place in the filament during the firing and the first forming

FIG. 9.
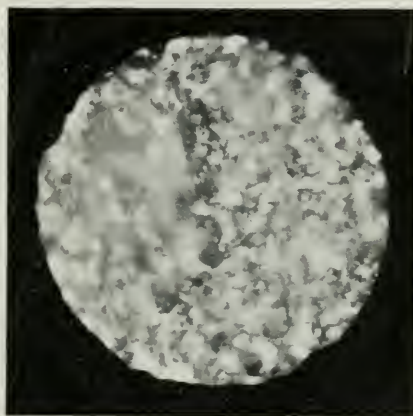
steps, as may be seen in Fig. 7. The black streak on this section does not indicate a crack but simply an unevenness in the broken surface. When the temperature reaches a certain point in the forming process a very sudden change takes place in the filament as Fig. 8 shows. The particles of tungsten have here drawn closely together and the binding material used in squirting has been practically eliminated. The reduction in diameter is about 20 per cent. and the fracture, previously dull black, is bright and metallic and shows a very fine structure. The effect of raising the temperature still higher is shown in Fig. 9. The fracture here shows a decidedly crystalline appearance. The crystals are small in size and are very uniformly distributed

over the cross-sectional surface. To carry the study a little
further Fig. 10 shows the fracture of a filament which had been
made up into a lamp and which had burned about 250 hours.
Evidently in this case at least there is a tendency for the size of
the grain to increase slightly with burning—particularly toward
the centre of the filament. Reference will be made to this latter
in connection with filament strengths.

Microscopic inspection of the longitudinal surface of tung-
sten filaments after various periods of operation show that a
gradual wrinkling or breaking up of the surface takes place.
Apparently the effect is confined almost entirely to the surface

FIG. 10.
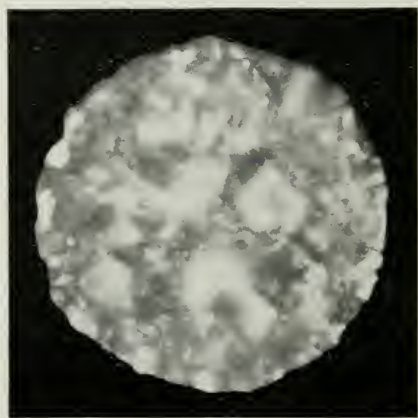
material, the filament itself suffers no serious distortion and no
marked difference in appearance is produced by burning on alter-
nating current. The appearance of the tantalum filament after
burning on direct current is not very different than that of a
tungsten filament but on alternating current, however, there is
a remarkable difference. A gradual breaking up of the tantalum
filament takes place and some rather extraordinary specimens
are sometimes found as seen in the accompanying figure (Fig.
11). The breaking up of the tantalum filament on alternating
current can hardly be ascribed to vibration due to rapid heating
and cooling because tungsten filaments, operated under similar
conditions do not show this tendency to " offset."

The study of the change in appearance of filaments throughout their life naturally leads to a consideration of the effect of burning on the strength of the filament.   Before discussing this matter, however, a few remarks about mechanical strength in general may be interesting.

It is important that the lamps possess considerable strength so as to render the breakage from shocks as small as possible. The fragility of the metallic filament lamps has been a considerable handicap in competition with other types and were it not for this one thing, their superior economy, better candlepower maintenance and improved quality of light would have made their use much more general to-day.

Fig. 11.

The ruggedness of an incandescent lamp depends upon two things: (1) the mechanical strength of the filament itself; (2) the method by which the filament is supported within the lamp. In order to investigate the relative strength of lamps of different types, various methods of testing them have been devised. Strength tests are made with the filaments cold because when they are heated it is practically impossible to break them, the most serious damage that can then result from shocks and blows being a twisting together of one or more loops.

One method of strength testing consists of mounting the lamp rigidly on a block which can be bumped by a second block allowed to swing as a pendulum.   The impact is regulated by the arc through which the pendulum is allowed to swing and is

increased by small increments until the filament is ruptured. The method has been modified by one investigator so that the impact is obtained through a ball rolling down an inclined plane. Another method requires the lamp to be mounted on a block which can be dropped from gradually increasing heights, the apparatus resembling somewhat a miniature pile driver. Other tests have been made by packing lamps in boxes as for shipment, and dropping the boxes from increasing heights, the lamps being frequently inspected. These methods have the advantage of breaking the lamps under conditions at least approximated in service, and moreover give some indication as to the value of the method used in supporting the filament. The results obtained are at best somewhat erratic and a large number of lamps must

FIG. 12.
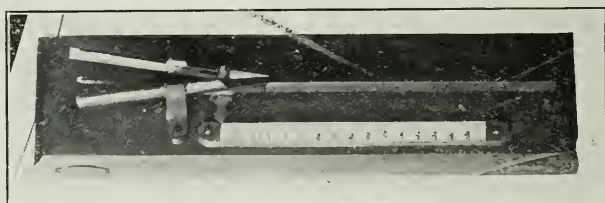
be averaged in order to obtain a proper appreciation of relative strengths.

In order to obtain some idea as to the strength of the filament itself, considered apart from its supporting structure, several methods of testing have been commonly used. One method consists in laying the filament on a pad of paper smooth but not rigid, and allowing a small metal cylinder to roll lengthwise along it. Rollers of increasing weights are used until the filament breaks. In another form of filament testing device shown in Fig. 12, the filament is drawn by a hook at the centre between two converging guides until it breaks, the distance which it was drawn into the " V " before breaking gives an arbitrary measure of its elasticity. This method has been varied in another device so as to draw the filament through a spiral guide, thus giving the sample a greater and greater curvature until it breaks. From the description of these methods it will be apparent that the strength could be measured in only an arbitrary way.

The number of ways in which filament strengths can be measured with precision is somewhat limited by the physical nature of the filaments and by their extremely small diameter. It is very probable that the elements of fatigue and ability to resist suddenly applied stress are important factors in determining filament strengths, but the difficulty of devising tests involving such elements makes it necessary to gauge the strength by some other means.

The filaments readily lend themselves to cross-bending tests and in order to carry out certain investigations, a device for making such tests with some degree of accuracy was constructed. To obtain the greatest amount of information from a cross-bending test it is desirable to measure not only the breaking

Fig. 13.

FILAMENT TESTING MACHINE
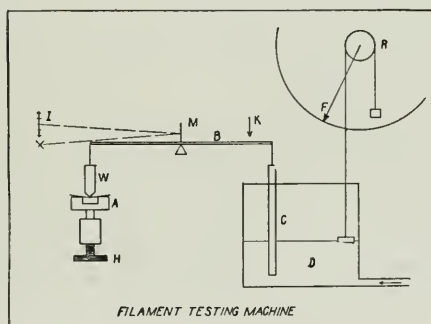
strength but the deflection as well. In the device mentioned, short pieces of filaments were supported at points 0.5 cm. apart and a load slowly applied at the middle until the filament broke, the load and deflection both being measured. By taking short pieces of filament it was possible to test from ten to twenty samples from a given lamp, and the average load and deflection given by these ten or twenty samples gives a very good measure of the filament strength in that particular lamp. In addition to determining the breaking strength, the deflection under various loads could be measured and deflection load diagrams could thus be obtained. Before discussing the results obtained in transverse bending tests a short description of the device with which the tests were made will be given, as it is believed that the application of the principle involved is new.

The machine (Fig. 13) consists essentially of a horizontal beam balanced on a knife edge, supporting at one end a cylindrical plunger (C) and at the other end a cylindrical weight (W) of the shape shown in the figure. The weight (W) at one end of the beam hangs with its lower edge midway between the points of support of the filament which is laid horizontally across an opening 0.5 cm. long. The block (A) carrying the filament can be raised through measured distances by means of a micrometer screw.

A small concave mirror (M) on the beam reflects light from the source to form an image at (I). By keeping this image on

FIG. 14.

FILAMENT TESTING MACHINE
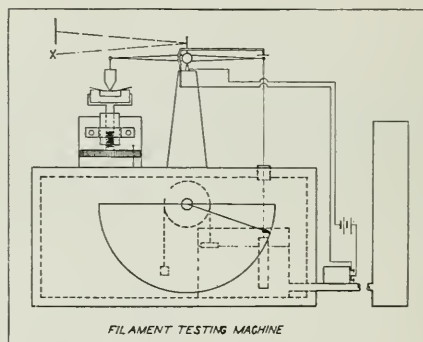
a certain point, the beam may be kept horizontal and the deflection of the filament may be read from the micrometer screw.

The plunger at the other end of the beam hangs within a vessel which may be filled slowly with water. The plunger is buoyed up by the water as the latter rises and a load proportional to the weight of water displaced by the plunger is thrown upon the filament. As the plunger is uniform in section, the volume of water displaced can be most easily measured by its height upon the plunger. In testing, the beam has been kept balanced with a small part of the plunger submerged and consequently the load upon the filament is determined by a difference in water levels. To enable the water level to be read with accuracy, a carefully balanced float rides upon the surface of the water

in vessel D and by means of a silk thread passing over the small pulley R its motion is magnified by the long pointer F travelling over an arbitrary scale. The water level readings can be reduced to the equivalent load in grammes on the filament by means of a calibration curve.

After putting the filament in place, and taking the initial reading of the pointer F and the micrometer head H water is allowed to flow into the vessel D. As this throws a load on the filament and produces a deflection, the operator raises the filament with the micrometer screw, in order to keep the image I at a fixed point. The loading continues until the filament breaks, at which instant the water supply is automatically cut off by electrical contact of the unbalanced beam with the point K. The pointer F indicates the water level at breaking and from the calibration curve the breaking weight can be expressed in grammes. The deflection of breaking is indicated by the difference between the initial and final readings of the micrometer head.

A more detailed drawing of this testing device which illustrates the general arrangement of parts is shown in Fig. 14.

In order to compare strengths and deflections of filaments of varying size, it was necessary to express the results in terms of some unit length and diameter. Consequently all measurements of strength and deflection have been reduced to the equivalent load in grammes and deflection in cm. of a filament 0.5 cm. long and 0.005 cm. in diameter. To perform this reduction, it was necessary to know the diameter of the test-pieces, and as the diameter of the filaments tested was about 0.004 cm. (1.4 mils) an optical micrometer was used. Individual readings of diameter could be checked within about 2 per cent.

In some cases filaments were found to be slightly elliptical in cross section rather than circular. The difference between the maximum and minimum diameter, however, rarely exceeded 10 per cent. In reducing the results of the cross-bending tests to a common basis, the diameter of the filament was therefore taken as the mean of two diameters at right angles in order to reduce the error due to possible deviation from a circular section. It can be shown where such deviation is small (10 per cent. or less), any two projected diameters at right angles

will give the same average within small limits of error,[6] and further that the percentage error in strength introduced by considering the mean of two such diameters as the diameter of an equivalent circular section, is approximately one-half of the percentage difference between the maximum diameters.[7]

Some of the most interesting tests made with the device just described have reference to the change in strength of the fila-

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[6] Showing average by using any two projected diameters.

ERROR INTRODUCED BY ELLIPTICAL CROSS SECTION
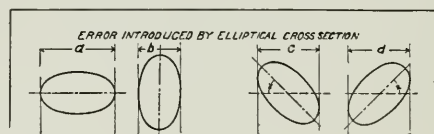
Ave. Dia.

$$D_1 = \frac{a+b}{2}$$

Ave. Dia.

$$D_2 = \frac{c+d}{2}$$

$(D_1 - D_2)$ is a maximum when $c = d$.

Ratio $\dfrac{b}{a}$ Deviation $\dfrac{D_1 - D_2}{D_1}$

1.0   0.00 per cent.
0.9   0.31 per cent.
0.8   0.55 per cent.

[7] Assuming a filament of elliptical section, let $a =$ maximum diam.; $b =$ min. diam.; and $d = \dfrac{a+b}{2}$. Strength of circular section varies as d^2. Strength of elliptical section varies as ab^2.

If $a = 1.1$
and $b = 1.0$
            $d = 1.05$
            $d^3 = 1.1576$
            $ab^2 = 1.1 \times 1.0^2 = 1.1000$
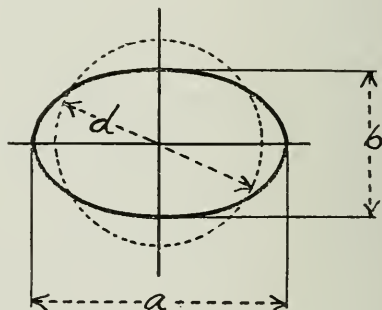
A circular section is about 5.2 per cent. stronger than an elliptical section of same mean diameter when the maximum diameter of the ellipse is 10 per cent. greater than the minimum. It is assumed that the filament having the elliptical section would break in the weakest direction.

ment during its life.   Three lots of 40-watt 110-volt tungsten-
filament lamps representing modifications in manufacturing pro-
cesses were run through such comparative test.   These lots may
be designated as *A, B* and *C*.   Special care was used in order
to have the filaments in the lamps of each lot very uniform.
Each lot was divided into two parts, one of which was burned
on 60-cycle alternating current and the other on direct current.
All lamps were burned at 1.23 w.p.c.   At certain intervals lamps
of each lot were removed from the burning racks and the strength
of the filaments tested.   The results of these tests can best be
shown graphically in Figs. 15, 16 and 17.
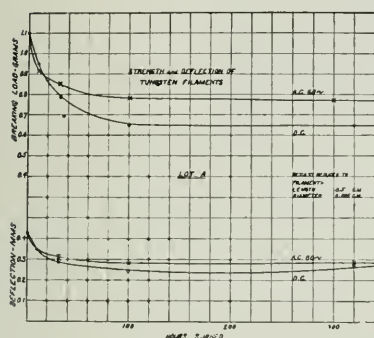
FIG. 15.   FIG. 16.
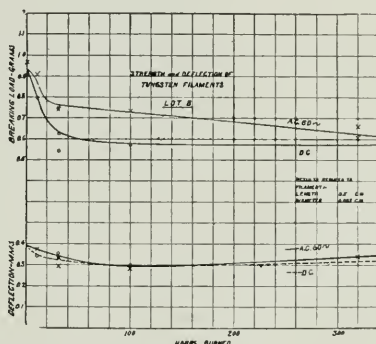
The change in strength and deflection with burning is shown
for lamps of each the three individual lots operated on both
alternating and direct current for periods up to 320 hours.
While each curve has been determined from the test of relatively
few lamps, the general tendency of the curves is about the same
in each case.   Each point on the curves is the average of 10
determinations of strength of the filament from a single lamp.
In lot *C* (Fig. 17) the probable error of each average is shown
by plotting a vertical line rather than a point and this serves to
give some idea of the uniformity of the data obtained from
individual lamps.   The deflection at breaking indicates that the
flexibility of the filaments does not change very much with
burning, especially after the first few hours.

The decrease in strength with burning could be most easily
shown by either some change in the structure of the filament or

by some change in the effective cross section. Although the results have all been reduced to terms of a uniform gross diameter, a microscopic inspection of the filament shows that there is a tendency for the surface to become wrinkled with burning which would, in all probability tend to reduce the effective diameter as far as strength is concerned. Since the breaking strength varies directly as the cube of the diameter, a reduction of 15 per cent. in this dimension would be sufficient to account for a reduction of 40 per cent. in strength. The filaments represented in the strength tests show that in general the surface which was originally smooth gradually becomes rough during the first 100 hours burning. Beyond this point the changes are not so

Fig. 17.
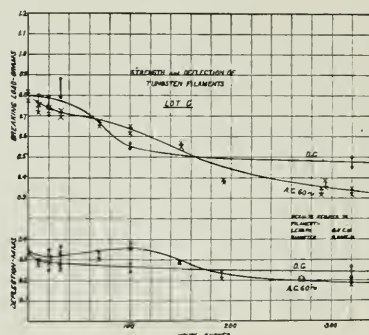
marked. The strength curves indicate in a general way that the greatest reduction in strength occurs, during the first one hundred hours of operation, and thereafter the change is less marked. This seems to point to the possibility that the strength is dependent at least to some extent upon the surface roughening. It might be noted that during the period covered by the test the gross diameter of the filaments of the several lots remain practically constant, *i.e.*, no marked reduction in diameter with burning could be noted.

In regard to changes in structure the cross sections of the large filaments previously shown indicate that there is a tendency for the crystalline structure to become somewhat coarser with burning. This change would naturally tend to weaken the filament due to the greater ease with which the fracture could

follow the larger crystalline surfaces. From an inspection of the cross section of the filaments represented in the strength tests it was found that lot *A* possessed in practically every case

Fig. 18.

a very compact crystalline structure, while lot *C,* which gave the least mechanical strength, showed in many cases a mixed structure, *i.c.,* partly crystalline and partly smooth, slightly

Fig. 19.

rounding surfaces resembling somewhat the appearance of certain large filaments, as shown in Figs. 18 and 19. Evidently the structure giving such smooth surfaces tended to decrease

the resistance to fracture. A compact small-grained crystalline structure is apparently the more desirable from the stand-point of strength. The investigation, however, should be carried further before any definite conclusions are reached.

In order to give the relative idea of the strength and stiffness of a tungsten filament and a glass thread, a glass rod was drawn down to a diameter approximately equal to that of the filaments and a number of samples were tested. The ultimate strength of the threads of glass was almost three times that of the filament (which was one of lot A burned 32 hours on D.C.), but the flexibility of the glass was considerably less, giving about 60 per cent. as great a deflection as a tungsten filament under the same load.

The Sterilization of Water by Chlorine and Ozone. G. SIMS WOODHEAD. (*Surveyor*, xxxviii, 114.)—About 1,000,000 gallons per day of the water supply of Cambridge, Eng., was treated with a solution of bleaching powder. One part of available chlorine per 7,000,000 to 8,000,000 parts of water completely destroyed non-sporing organisms within 20 minutes and left no taste nor smell of chlorine. The proper amount of "bleach" was gauged by tests of the treated water after contact with potassium iodide and starch. The test should give a violet color to the water; a deep blue color shows too much "bleach" has been used. If the right amount is used it is unnecessary to neutralize any excess of chlorine with sodium bisulphite. The same water was freed from *B. coli* by ozonization with the Siemens-Halske apparatus. Although this process is not so simple and is more expensive than the chlorination process, it has advantages from an æsthetic point of view. In experiments carried out with ultra-violet rays, sterilization was effected at once.

A New Radiation Pyrometer. ANON. (*Amer. Mach.*, xxxiii, 1036.)—The Brown Instrument Co. of Philadelphia has recently brought out a new pyrometer of the fixed-focus type. This pyrometer has a finder somewhat similar to those used on kodaks which has been placed on the tube, and by means of this, the tube can be readily pointed directly at the furnace opening. It also acts as a measure of distance, and it is only necessary that the bright red of the furnace opening takes up the whole view in the finder. If some of the dark outside wall of the furnace is showing around the bright red opening, the tube is too far distant, and should be moved closer, until only the bright red is showing. The instrument is accurate under ordinary working conditions within 1 per cent., or 30° at 3000° F.

THE PREPARATION AND TESTING OF DRUGS.[*]

BY

WILLIAM A. PEARSON, Ph.C., Ph.D.,

Professor of Chemistry and Toxicology in the Hahnemann Medical College of Phila-
delphia; Chemist to Smith, Kline and French Company.

DRUGS may be defined as substances which are used for the
prevention or alleviation of disease. Logically they fall into three
great divisions:

1. Medicinal chemicals.
2. Preparations made from plants.
3. Biological products.

MEDICINAL CHEMICALS.

The quantity of chemicals used for medical purposes is very
small, compared to the quantity which finds technical application.
On this account manufacturing chemists will not strive to prepare
chemicals especially for pharmaceutic use. Moreover, scientific
methods and elaborate processes have made possible the manu-
facture for technical use of acids and salts which are sufficiently
pure for medicinal purposes, as a rule. It is proper and logical
that the great chemical industries with their knowledge, equip-
ment, and experience should prepare medicinal chemicals,
although the degree of purity of these compounds is governed
to a great extent by their technical use. Thus magnesium sul-
phate (Epsom salt) is used extensively in medicine, but to a
far greater extent in the leather industry. The commercial
product is quite pure, but usually contains from one-tenth to three-
tenths of 1 per cent. of magnesium chloride, which does not
interfere to an appreciable extent with the medicinal properties
of the sulphate, yet is responsible, to a large extent, for the
bitter taste of the latter. The magnesium chloride can be removed
at an additional expense, however the public desires the com-
mercial product, as is shown by the protest against paying the
higher price for the purer article. In another case the keen

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[*] Presented at a Stated Meeting of the Section of Physics and Chemistry,
held Thursday, January 5, 1911.

rivalry in the baking powder industry, and the consequent improvements in the manufacture of potassium bitartrate (cream of tartar) have made possible the production of that salt about 99.98 per cent. pure, on a commercial scale at a low cost. There is no reason why any of the chemicals used in medicine cannot be purified to the same degree, with the same expenditure of labor. However, this is unnecessary in the majority of cases, since the small amount of impurity is often innocuous.

When pharmacology and physiological chemistry determine the exact relation between physiological action and chemical constitution, chemical industry may be depended upon to prepare almost any desired compound, however intricate. The development of therapeutics will be along this line, thus dioxydiamido-arsenobenzol was deliberately planned and prepared.

Since the preparation of medicinal chemicals is so intimately related to the world's great chemical industries, any attempt to describe the manufacture of these compounds would require more time than is available this evening. Two extensive establishments may be chosen as representative, one in Darmstadt, Germany, the other in our own city; both are engaged extensively in the manufacture of medicinal chemicals, although other establishments also occupy important positions in the preparation of this class of pharmaceuticals. The house of Merck in Darmstadt has been in business for approximately two hundred and fifty years, and prepares almost every chemical compound used in medicine. The Powers-Weightman-Rosengarten Company was formed by the consolidation of two large corporations, both of which were established nearly a century ago, and have contributed largely toward making Philadelphia the centre of pharmaceutical activity of this continent.

PREPARATIONS MADE FROM PLANTS.

Medical preparations made from plants are usually classified as " straight pharmaceuticals "; this designation is applied particularly to those preparations known as fluid extracts, extracts, tinctures, pills, tablets, tablet triturates, capsules, elixirs, emulsions, ointments, etc. Brief definitions of these terms may be given.

Fluid extracts are liquid preparations of such strength that one cubic centimetre of the liquid contains the active principles of one gramme of the drug.

Extracts may be considered a fluid extract concentrated by evaporation, and may be in a plastic condition or in the form of a powder. Whenever heat exerts a destructive action upon the active principles, the evaporation is conducted in vacuum.

Tinctures are similar to fluid extracts, but usually are one-tenth as strong as the latter.

Fluid extracts and tinctures are prepared by means of an apparatus called a percolator, which is a tubular container with a small opening at the bottom. The ground drug is placed in the percolator and the active principle is extracted by permitting a suitable solvent to seap through it. The size and shape of the percolator, the menstruum used, the fineness of the powder to which the crude drug previously has been ground, and the rate of flow of the solvent depend upon the properties of each drug.

Tablets are compressed by machines, some of which have a capacity of 500 tablets per minute. The material to be compressed must be granulated so that it will feed uniformly in the machine and hold together properly after being compressed. Moreover, the tablets must be so prepared that they will disintegrate properly when used.

Some confusion exists concerning the distinction between a tablet and a tablet triturate. Tablet triturates are made by gently pressing a moist powder into moulds which hold from 25 to 1000, allowing to dry and then removing from the mould.

The gelatin capsule industry is confined to a few large establishments, where the capsules are prepared by elaborate machinery in enormous quantities. The hard capsules are made by dipping brass pins into the melted gelatin, drying, cutting away the excess of gelatin and fitting on the caps, which are made in the same way but are slightly larger. The proper consistency of the gelatin plays an important rôle in the manufacture of capsules. It is interesting to note that there are at least two different successful machines on the market, which remove the caps from the empty capsules, fill the capsules and adjust the caps again; the machine is able to fill 50,000 capsules per hour.

In the manufacture of soft capsules and globules, a layer of the medicament is placed between two layers of gelatin, and the entire mass is subjected to pressure between the upper and lower dies of a. press.

Pills are made by a special machine, direct from the plastic mass. This machine first rolls the mass into a long, thin cylinder,

then cuts this into a number of smaller cylinders, and finally rolls each small cylinder into a pill. The machine will prepare from 50,000 to 500,000 pills in a day of ten hours. In the preparation of the plastic mass certain problems arise, it must have a certain consistency and remain soluble, moreover the medicinal constituents must be evenly distributed throughout the entire mass.

" Friable " pills are manufactured from a moist nucleus by adding successive layers of powder, just as a snowball is increased in size by rolling over the snow.

Crude drugs for the preparation of homœopathic medicines are usually imported, packed in alcohol; from them tinctures, tablet triturates and other preparations are manufactured. The largest manufacturers of homœopathic medicines are located in Philadelphia.

BIOLOGICAL PRODUCTS.

These products are made either directly or indirectly from pathogenic (disease-producing) microörganisms. They are of two general types—the Antitoxins and the Vaccines.

In the preparation of antitoxins, animals are rendered immune to the toxins or poisons produced by the microörganisms in their development, and the blood-serum of these immunized animals is used for combating the corresponding disease. Satisfactory antitoxins have been prepared for only diphtheria and tetanus, although they are considered of value in some few other infectious diseases. In both diphtheria and tetanus, the toxin or poison, given off during the development of *Bacillus diphtheriæ* and *Bacillus tetani* respectively, is responsible for the alarming symptoms and death caused by these diseases. The antitoxins actually neutralize these toxins and the patient usually recovers. The details of the manufacture of antitoxins are too intricate to permit a full description of the technic.

Vaccines are attenuated (stunted) cultures of pathogenic microörganisms. Their efficiency depends upon the fact that they produce a mild attack of the disease, which results in subsequent immunity to the disease. Smallpox vaccine is the best known vaccine; it is allowed to develop upon the belly of young heifers, since no suitable artificial medium has yet been discovered.

The bacterial vaccines are prepared in various ways from cultures of microörganisms on artificial media; in some cases

they have been used with success as diagnostic and curative agents.

Future progress in therapeutics will no doubt be made largely through the agency of bacterial vaccines and other biological products.

THE RELATION OF THE MANUFACTURER, WHOLESALER, AND RETAILER TO EACH OTHER.

The large manufacturer of drugs has certain advantages over the retail pharmacist in the preparation of pharmaceutical products. The manufacturer is able to prepare the finished drug far more economically than the retailer. A concrete example may be given of the decrease in price of a pharmaceutical product as the result of its manufacture on a large scale. According to Jacob Dunton, the pioneer tablet manufacturer, one hundred quinine tablets were sold for four and one-half dollars in the year 1877; to-day the same number of tablets may be purchased for a few cents.

The manufacturer is able to purchase crude drugs in large quantities and has the facilities for preparing from them enormous quantities of the finished product, lastly and most important he can assay and standardize a large quantity of the final product with the same expenditure of time and labor as the retailer must expend in testing a small quantity of his own preparation; hence greater uniformity and reliability are to be expected in the product of the manufacturer. However, on the whole, the retail pharmacist manufactures from the crude drug an enormous quantity of medicines, including aromatic waters, infusions, solutions, prescriptions, and such preparations as are dispensed extemporaneously. This practice is to be encouraged.

All the large drug laboratories have been developed since 1860. Certain of the products of each manufacturer were received with greater favor than the same preparations of other manufacturers, either because of superiority, price or other reasons. As other manufacturers entered the field, competition became keener and to a large extent the profits were eliminated on those preparations in which competition was greatest. In this state of affairs each manufacturer increased his attention to those products of his plant for which the demand was greatest, and thus made a specialty of those products. Thus one firm

specializes in the preparation of elixirs, another in the manufacture of ether for anæsthesia; other firms devote their attention to dental pharmaceuticals, capsules, medicines for domestic animals, insecticides, fungicides, and other special lines.

The increase in number of manufacturing laboratories and the consequent increase in competition exerted an influence on the wholesale druggist. The newer manufacturers experienced difficulty in disposing of their preparations through the wholesaler, and therefore sold directly to those retail dealers who transacted sufficient business to warrant the purchase of drugs in large quantities. As a result the business of the wholesalers decreased in volume and they were unable to purchase from the older manufacturers to such an extent as formerly. Thereupon the older manufacturers also began to sell directly to the retailers with consequent loss to the wholesalers. In order to retain the prestige of their patrons, the wholesalers began the manufacture of pharmaceutical and medicinal preparations.

THE DRUG TRADE OF THE UNITED STATES.

The following data will convey an idea of the magnitude of the drug trade of the United States:

Philadelphia has always played a leading rôle in pharmaceutical progress, as has already been described by Dr. Lowe in his paper on " Pharmacy in Philadelphia," which was published in the *Pharmaceutical Era* for 1908. A number of large manufacturing druggists are located in Philadelphia, others are to be found in Baltimore, Brooklyn, and the northern portion of the Middle West, *e.g.,* in Detroit, Chicago, and Indianapolis. The business transacted by these manufacturers, at home and abroad, is enormous; for instance, a single manufacturer employs three hundred and sixty travelling salesmen. Several of the manufacturing druggists maintain branch laboratories in Canada and one firm has such a laboratory in England. The foreign trade is quite extensive, extending even to Latin America and Australasia. The large wholesale druggists likewise are located in the Middle Atlantic and Northern Central States, especially in the cities of Philadelphia, New York, Chicago, St. Paul, and St. Louis. The total annual sales of five of the more prominent manufacturing laboratories amounts to eighteen million dollars, a sum but slightly below the tax levy of 1908 in Philadelphia. The total

annual sales of three of the larger wholesale druggists amounts to fifteen and one-half million dollars, which is about one and one-half times the expenditure for public schools in Philadelphia for the year 1908.

RESEARCH WORK.

The public in general and the physician in particular are deeply indebted to the manufacturers of pharmaceutical products on account of the extensive, systematic researches which are made by all the larger establishments; these researches lead directly to marked advances in therapeutics and medication. The manufacturer is better prepared to solve the many problems of modern medicine than either the retail pharmacist or the practicing physician. Of course, the manufacturer directly reaps some benefit from these researches—he deserves it—but all information not closely related to methods of manufacture is given freely to the medical profession.

Old products are improved and new ones conceived, prepared and standardized. After complete chemical, physiological, and clinical tests have been made, the medical profession is given the benefit of this work. Large research laboratories have been erected by the manufacturing druggists; in America, those situated in Philadelphia, Detroit, and Indianapolis deserve special mention for the excellence of the work which has been carried out within their walls. In addition to the experimental work in the manufacture of pharmaceutical preparations, researches are also being made in pharmacology, pathology, and chemistry in these laboratories.

The day is not far distant when the manufacturers will raise their own drugs. For several years belladonna has been grown with success for the manufacture of plasters. The cultivated drug has not proved inferior to the wild drug and is probably superior to the latter in its alkaloidal content.

If a better conception of the pharmaceutical industry has been given to the members of the Franklin Institute, my purpose has been accomplished.

[During the lecture a number of lantern slides were shown, depicting various pharmaceutical laboratories, and the manufacture and testing of drugs therein. Information was given as to the capital, yearly sales and special preparations of each laboratory.]

FRANKLIN INSTITUTE

Additions to membership since last report, 3.

The resolution from the Board of Managers recommending General James Allen, Chief Signal Officer, U. S. Army, for honorary membership was adopted.

The Chairman then introduced Prof. George W. Ritchey, of the Mt. Wilson Solar Observatory, Pasadena, California, who delivered an interesting address on "Recent Astronomical Photography."

The speaker described the construction of refracting and reflecting telescopes and the equipment of large astronomical observatories, referring especially to those of the Mt. Wilson Observatory. He presented illustrations of the instruments of this observatory and their housing; views were shown of the surrounding country and the obstacles which were encountered in transporting the various parts of the apparatus over roads especially constructed, to the top of the mountain.

Lantern slides were shown of the workshop in which glasses of sixty and one hundred inches are being ground for the reflecting telescopes.

Remarkable photographs of star clusters and nebulæ were exhibited during the course of the lecture.

The thanks of the meeting were extended to Dr. Ritchey and his interesting address was referred to the Committee on Publications. Adjourned.   R. B. OWENS,
                                                            Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

The following reports were presented for final action:

No. 2455.—Hardinge Conical Ball and Pebble Mill. (Referred back to subcommittee.)

No. 2461.—Shore Scleroscope (Hardness Testing Apparatus). (Scott Medal.) Adopted.

No. 2476.—Roper Safety Propeller. (Referred back to subcommittee.)

No. 3489.—Hopkins' Speedometer and Dynamometer. (Longstreth Medal.) Adopted.

The following report was presented for first reading:

No. 2469.—Crisfield Moisture Determinator for Coke, etc. (Referred back to subcommittee.)

R. B. Owens,
Secretary.

SECTIONS.

Mechanical and Engineering Section.—A meeting of the Section was held on Thursday, February 23, 1911, at 8 o'clock, P.M. In the absence of the regular officers of the Section the meeting was called to order by Dr. Owens, Secretary of the Institute; 40 members and visitors were present.

An invitation was extended to those present to attend the lecture by Dr. L. H. Bailey of Cornell University at the Harrison Laboratory of Chemistry, University of Pennsylvania, on the evening of February 27th, under the auspices of the Pennsylvania Chapter of the Society of the Sigma Xi.

The Chairman then introduced Mr. Henry G. Brinckerhoff, of Boston, who presented a communication on natural and artificial draft.

The problem of draft and its proper application in power plants was given full consideration. Suggestions were made as to the height and area of chimneys and their location, and various methods and apparatus for induced and forced draft were described and illustrated by means of lantern slides.

A brief discussion followed the paper, in which the Chairman, Messrs. Crisfield, Gartley, Parker and others participated.

On motion duly seconded, the thanks of the meeting were extended to the speaker. Adjourned.

Alfred Rigling,
Acting Secretary.

Joint Meeting of the Electrical Section of the Franklin Institute and the Philadelphia Section of the American Institute of Electrical Engineers.

The first joint meeting of the above sections was held on Thursday evening, March 2d at eight o'clock in the hall of the Institute.

Mr. W. C. Eglin and Mr. Chas. F. Young acted as joint Chairmen of the meeting; 360 members and visitors were present. Mr. Young called the meeting to order and congratulated the members of the two societies on the successful beginning of their coöperative work. He then introduced Dr. Chas. Proteus Steinmetz of Schenectady, N. Y., who addressed the meeting on " Some Unexplored Electric Fields." He reviewed the progress of electrical investigation and referred to the theories which had been proven to be incorrect, or about which there is still considerable speculation.

Among the subjects given consideration were certain electrostatic phenomena including lightning, the resistance to the flow of alternating current in trolley rails, some unexplained phenomena of magnetism, the conduction of current in gases, the arc, etc.

He also called attention to the so-called electric fishes and the descriptions given of them in the works on natural history and stated that there was some mystery in this case, as it is inconceivable that they could develop, even momentarily, some hundreds of kilowatts of electric power.

In the discussion following the reading of the paper, Dr. Hoadley, Messrs. Snook, Calvert, Hixon, and a number of others participated.

A vote of thanks was extended to Dr. Steinmetz and the meeting then adjourned.   R. B. Owens,
                                                                                                        Secretary.

Section of Photography and Microscopy.—A meeting of the Section was held on Thursday evening, March 9th, at eight o'clock; 45 members and visitors were present.

The meeting was called to order by Dr. Henry Leffmann, Chairman of the Section, and in the absence of the Secretary the reading of the minutes was dispensed with.

The communication of the evening on " Some Unusual Photographic Processes " was presented by the Chairman.

The speaker described numerous peculiar processes including the several methods for producing photographs in colors. The subject was illustrated by many lantern slides of unusual interest.

A specimen of carbon photograph on canvas was exhibited by Mr. Chas. Truscott, and slides of crystals of various chemicals and recent examples of photographs in colors were shown by others present.

                                                                                    Alfred Rigling,
                                                                                        Acting Secretary.

Mechanical and Engineering Section.—A meeting of the Section was held on Thursday evening, March 16th at eight o'clock. In the absence of the Chairman the meeting was called to order by Dr. R. B. Owens, Secretary of the Institute. Sixty members and visitors were present.

After the reading and approval of the minutes of the previous meeting the Chairman introduced Dr. Allerton S. Cushman, Director of the Institute of Industrial Research, Washington, D. C., who presented an interesting communication on the " Conservation of Iron."

The speaker presented interesting facts and statistics on the uses of iron and its destruction by rust, electrolysis and other means. Lantern slides illustrating the effects of salts and acids on iron, the formation of rust, the protective qualities of zinc and other related subjects were shown.

In the discussion which followed the reading of the paper Messrs. Colvin, Crisfield, Head and others participated.

A vote of thanks was tendered Dr. Cushman and his paper was referred to the Committee on Publications.

                                                                                    Alfred Rigling,
                                                                                        Acting Secretary.

MEMBERSHIP NOTES.

Elections to Membership.

RESIDENT.

Mr. J. P. Magill, Care Fayette B. Plumb, Inc., Frankford, Philadelphia.
Mr. Jacob G. Biswanger, 1619 North Sixteenth St., Philadelphia.

NON-RESIDENT.

Mr. H. P. Tyson, Collegeville, Pennsylvania.

Changes of Address.

Mr. Charles A. Sims, 2704 Cathedral Ave., Washington, D. C.
Mr. James S. Whitney, 206 Weightman Bldg., Philadelphia.
Mr. H. M. Bush, 508 Capitol Trust Bldg., Columbus, Ohio.

NECROLOGY.

Mr. James Elverson, *The Philadelphia Inquirer,* Philadelphia.

Mr. Elverson was born in England in 1838. He came to the United States in 1847 with his parents and was educated in the schools of Newark, N. J. He was one of the founders of the *Saturday Night,* and in 1880 established *Golden Days,* a weekly publication. Since 1879 he has been proprietor and publisher of *The Philadelphia Inquirer.*

LIBRARY NOTES.

Purchases.

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Scientific American Cyclopedia of Formulas, 1911.
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American Society of Mechanical Engineers, Yearbook for 1911. New York, 1911. (From the Society.)
Massachusetts, State Board of Health, 41st Annual Report, 1909. Boston, 1910. (From the Board of Health.)

Finland—XI. undersökning rörande Nattarbeterskorna I Finland's Industrier. Helsingfors, 1910. (From the Patent Office.)

Delaware, Board of Water Commissioners. 41st Report 1909–1910. Wilmington, 1910. (From the Commissioners.)

Wisconsin—State Historical Society, Proceedings 58th Annual Meeting, 1910, Madison, 1911. (From the Society.)

Western Australia Geological Survey, Bulletins No. 38–39 of 1910. Perth, 1910. (From the Agent General.)

JENKINS, C. FRANCIS, and OSCAR B. DEPUE.—Handbook for Motion Picture and Stereoptican Operators, Washington, D. C. (n.d.) (From Mr. C. Francis Jenkins.)

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U. S. Department of Agriculture, Report of the Secretary for 1910. Washington, 1910. (From the Department.)

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U. S. Department of Commerce and Labor, Results of Observations made at the Coast and Geodetic Survey Magnetic Observatory at Cheltenham, Maryland, 1907 and 1908. Washington, 1911. (From the Department.)

Missouri Bureau of Geology and Mines, Biennial Report of the State Geologist, 1909–1910. Jefferson City (n.d.) (From the Bureau.)

San Fernando, Instituto y Observatorio de Marina, Almanaque Nautico para el ano 1912. San Fernando, 1910. (From the Observatory.)

Massachusetts Board of Education, 74th Annual Report, 1909–10. Boston, 1911. (From the Board.)

DUNN, SAMUEL O.—Current Railway Problems, New York, 1911. (From Railway Age Gazette.)

New York State Education Department—91st Annual Report of the State Library, 1908. Parts 1 to 3 and Yearbook of Legislation, vol. 10, 1908. Albany, 1910. (From the State Library.)

Vermont State Documents, Sixth Biennial Report of the State Highway Commissioner 1909–10; Forty-first School Report 1910; Annual Report of the Banking Commissioner 1910; Legislative Directory, Biennial Session 1910; Seventh Biennial Report of the State Geologist 1909–1910; Vermont State Documents, 1909–1910. Montpelier, 1910. (From the State Library.)

CORRESPONDENCE.

JOURNAL OF THE FRANKLIN INSTITUTE:

Some years ago, about 1880, there was published in your JOURNAL by myself, "Mechanics of the Flight of the Bird." . . . .

I have given the subject some thought since that "long ago" and now that the public is so thoroughly aroused at the wonderful achievements of aerial navigation, I am persuaded to revive and enlarge upon the subject. The article is indexed in my name.

Yours truly,

A. C. CAMPBELL.

Jan. 27, 1911.

(From the Editor to Mr. Campbell.)

. . . We take pleasure in sending you under separate cover a copy of the June issue 1881, of the JOURNAL OF THE FRANKLIN INSTITUTE containing your article on "The Flight of Birds." . . . If you finally decide to revise the article and bring it up to date, we should be glad to have you send us the manuscript, if you feel disposed to do so, in order that we may submit it to our Committee on Publications with a view to having it form a supplement to the original communication.

ASHEVILLE, N. C., Feb. 6, 1911.

THE EDITOR,

THE JOURNAL OF THE FRANKLIN INSTITUTE:

I received your letter of the 27th Jan., also the June issue of the 1881 JOURNAL OF THE FRANKLIN INSTITUTE which was a great surprise to me, and gives me much pleasure. I do not find, however, that I can make any improvement by revising the article. It is correct as far as it goes, and is thoroughly up-to-date. To enlarge upon the various principles, I fear, would put it out of favor for publication in any periodical.

I have long entertained the idea of putting into practice the principle of impact of air, in mechanical flight, and am quite sure that successful navigation will in the future result from this principle, rightly applied. On the other hand, many of the sad accidents are due, no doubt, to treacherous impulses of air, that come unawares, like the death dealing bullet from the gun, "Didn't know the thing was loaded." We should be able to carry a greater burden with diminished power, when the principles of impact of air are embodied in an aeroplane more nearly akin to the bird, since we know that mechanical principles practice no favoritism.

My attention was caused to revert to my publication of thirty years ago by reading the late popular periodicals, particularly the *Cosmopolitan*, February 1911, "The Wonderful New World Ahead of Us," by Thomas

A. Edison, pages 297 and 298. He seems to have fallen heir to my ideas, has rejuvenated them and put them on dress parade, in these times when antiquities are much in favor. I believe Mr. Edison is wrong, however, in his conclusions on how the buzzard soars. Soaring has never yet been proven; mathematically, mechanically, or demonstrated experimentally. The problem remains for future study, followed by experimental research looking to actual sustaining flight by aid of *wind*. I believe that it is generally conceded that the bird cannot soar except by aid of wind; else perpetual motion would be possible. Hence I venture to assert that Mr. Edison's sound waves come only as an *effect* of a force of air that gives the buoyancy, similar to the rhythmical impulses of the Rife hydraulic ram.

It shall be my pleasure to take up this problem in the immediate future, feeling that it is not so difficult as it seems; since all mechanical energy may be diverted into various channels, just as curvilinier motion may be changed to rectilinier motion, and the two factors of a given energy, mass and velocity, being infinitely variable.

I should be glad to encourage others to participate in the strife for an early solution of the problem, " The Mechanics of the Flight of Birds "— to the public.

<div align="center">Yours truly,</div>

<div align="right">A. C. CAMPBELL.</div>

BOOK NOTICES.

SMOLEY'S TABLES. Parallel Tables of Logarithms and Squares; Angles and Logarithmic Functions Corresponding to Given Bevels; Five Decimal Lotharithmic-Trigonometric Tables; Natural Trigonometric Functions Including Secant and Cosecant; Squares, Cubes, Square Roots, etc. By Constantine Smoley, C. E., Assoc. M.A.S.C.E., Principal School of Civil Engineering, I.C.S. Schools, xi + 503 pages, 7 x 4½ inches, flexible morocco. Sixth edition, revised and enlarged. Price $3.50 net. The Engineering News Publishing Company, New York, 1911.

One of the most frequent computations a designer of framed structures is called upon to perform is that involved in the solution of a right triangle. How irksome this is without the assistance of special devices, those who have much of such work to do, only too well know. Smoley's Tables are primarily intended to lighten this labor. Parallel tables of squares and their logarithms are given for each one thirty-second of an inch to fifty feet, and for each one sixteenth from fifty feet to one hundred feet. The logarithms and other tables that follow are additions to recent editions. That the tables have proved their value by extended adoption is attested by the issue of six editions since the first appearance in 1901. The work appears to contain every table the structural or mechanical designer is likely to need, with perhaps one exception,—a table of circular arcs expressed in radians. Such a table occupies only one page and its usefulness is many fold the space it occupies.

MOTION STUDY. A Method for Increasing the Efficiency of the Workman. By Frank B. Gilbreth, Member Am. Soc. Mech. Engineers, with an Introduction by Robert Thurston Kent, Editor Industrial Engineering. xiii + 116 pages, 8 x 5½ inches, cloth with 44 illustrations. Price $2.00 net. D. Van Nostrand Company, New York, 1911.

In modern manufacturing the various operations necessary in producing a large number of duplicates of an article are subdivided, classified and systematized to the greatest nicety with a view to increasing the output and economy of production. Such a mode of procedure is comparatively common, and at the present day excites little comment. In the development of a system of economic production, the sequence as well as the means of performing the required operations is the subject of close analysis.

Motion study is a somewhat similar system of even more minutely investigating the operations for the production of a required result. Not alone are the mechanical features of manual operations analyzed but physiological and psychological influences as well are considered. In short the aim is to study every feature affecting the movement of the hands and body with the object of simplifying such movements or reducing their number, and so decreasing the effort of performing a given operation. The author being identified with building operations on a large scale, has applied the study to bricklaying with most favorable results, the account of which serves as a concrete example of what may be accomplished by an analysis of this kind. Motion study has undoubtedly received prior attention resulting in increased output and improvement in quality, but such investigations have related more to materials and machines rather than to the personal characteristics of the individual operative. In that field the author appears to have broken new ground, and opened a region of research that may prove of the greatest value alike to the workman and the employer.

PUBLICATIONS RECEIVED.

U. S. Department of Commerce and Labor, Bureau of the Census. Cane and beet sugar. Summary of results of the census in 1909. 6 pages, 8vo. Washington, Government Printing Office, 1911.

U. S. Department of Commerce and Labor Results of Observations Made at the Coast and Geodetic Survey Magnetic Observatory at Cheltenham, Maryland, 1907 and 1908. By Daniel L. Hazard, computer, division of terrestrial magnetism. 93 pages, plates 4to. Washington, Government Printing Office, 1911.

Russia and the American Passport. Address by Louis Marshall of the New York bar to the delegates at the twenty-second Council Union of American-Hebrew Congregations, Thursday, January 19, 1911, together with resolutions unanimously adopted. 16 pages, 8vo. New York, American-Jewish Committee, 1911.

Canada Department of Mines. Bulletin No. 4, 2nd edition. Investigation of the peat bogs, and peat industry of Canada during the season 1909–10. By Aleph Anrep, Jr., peat expert. To which is appended Mr. Alf Larsen's paper on Dr. M. Ekenberg's wet-carbonizing process; from Teknisk Tidskrift, No. 12, December 26, 1908. Translated by Mr. A. Anrep, Jr., also a translation of Lieut. Ekelund's pamphlet entitled, A Solution of the Peat Problem, 1909; describing the Ekelund process for the manufacture of peat powder. By Harold A. Leverin, Ch. E. 44 pages, illustrations, maps, 8vo. Ottawa, Government Printing Bureau, 1910.

Canada Department of Mines. Bulletin No. 5. Magnetic concentration experiments with iron ores of the Bristol mines, Que.; iron ores of the Bathurst mines, New Brunswick; a copper nickel ore from Nairn, Ontario. By George C. Mackenzie, B.Sc. 28 pages, tables, 8vo., Ottawa, Government Printing Bureau, 1910.

First Universal Race Congress, University of London, July 26–29, 1911. Announcement, list of officers, programme of meetings. 16 pages, 12mo. London, Executive Committee. (n.d.)

Eighth International Congress of Applied Chemistry, Washington, 1912. Preliminary announcement. 31 pages, 8vo. New York. (n.d.)

The Broader Aspects of Research in Terrestrial Magnetism. By L. A. Bauer. Address of the retiring vice-president and chairman of Section B (physics), American Association, for the Advancement of Science, at the Minneapolis meeting, December 29, 1910. Reprinted from Science, N.S., vol. 33, No. 837 pp. 41–54, January 13, 1911. 30 pages, 8vo. Lancaster, Pa., 1911.

Carnegie Institution, Washington. Annual Report of the director, department of terrestrial magnetism, 1910. Reprinted from Yearbook No. 9, pages 195–204, plate 5. 10 pages, map, 8vo. Washington. (n.d.)

U. S. Department of Commerce and Labor. Bureau of the Census. Forest products, No. 7. Wood distillation, 1909. Compiled in coöperation with the Department of Agriculture, Forest Service. Henry S. Graves, forester. 11 pages, 8vo. Washington, Government Printing Office, 1911.

U. S. Department of Commerce and Labor, Bureau of the Census. Rice, cleaning and polishing. Preliminary comparative report for 1909. 7 pages, 8vo. Washington, Government Printing Office, 1911.

U. S. Department of Commerce and Labor. Bureau of the Census. Turpentine and rosin. Preliminary comparative report for 1909. 5 pages, 8vo. Washington, Government Printing Office, 1911.

Galvanostegie. I. Teil über elektrolytische metallniederschläge von Dr. Ing. M. Schlötter. 257 pages, illustrations. 8vo. Halle, a. S., Wilhelm Knapp, 1910. Price in paper, 12 marks.

CURRENT TOPICS

The Effect of Tarring Roads. MARCEL MIRANDE. (*Mon. Scientifique,* lxxiv, 66.)—The noxious influence of tarring on plants is due to the action of the disengaged gases and not to dust containing caustic elements. The tarring of embanked streets and avenues, such as are bounded by tall houses, can be very hurtful to trees planted on the sidewalks; the same thing can occur in open avenues with dense vegetation on the sides. Tarry dusts only act upon vegetation as *dust* if in sufficient quantity as to be a nuisance.

Electrolytic Preparation of Calcium. F. C. FRARY. (*Bull. Soc. d'Encour.,* cxiv, 459.)—In the electrolytic preparation of calcium it is necessary to use an artificially cooled cathode. The current density is only of importance in so far as it affects the temperature of the cathode. The chloride gives a better yield than a mixture of chloride and fluoride. Calcium is produced on a commercial scale by a Rathenan furnace at the Bitterfeld works. The electrolyte should be added continuously, and the cathode be raised regularly to remove the calcium.

Incandescent Lamps. G. RICHARD. (*Bull. Soc. d'Encour.,* cxiv, 500.)—The tungsten lamp has chiefly attracted the attention of electricians, on account of the recent improvements in making the filament more ductile and more resistant. At ordinary temperatures tungsten is exceedingly hard and brittle. It softens at the temperature of incandescence, but cannot be drawn into wire. To obtain wire-drawn filaments very pure tungsten is mixed with certain secret substances, which are afterwards volatilized. This leaves the metal ductile with a higher tenacity than steel. Analogous results have been obtained with molybdenum.

The Action of Air on Chloride of Lime. JULES GARÇON. (*Bull. Soc. d'Encour.,* cxiv, 454.)—Many researches have been made on the action of carbon dioxide and of air, on chloride of lime, or bleaching powder. When carbon dioxide reacts with it, either in powder or dissolved, chlorine only is given off. Air, deprived of all carbon dioxide, slowly liberates a little hypochlorous acid. Ordinary damp air acting on the powder, liberates at first a mixture of hypochlorous acid and of chlorine, then chlorine only. It has the same effect on the solution. Air, freed from carbon dioxide, sets free considerable quantities of chlorine from a solution of chloride of lime, containing no free lime.

To Prevent Dusting or Easy Abrasion of Improperly Laid Concrete Floors. ALBERT MOYER. (*Vulcanite Portland Cement Co.*)—Cement floors, particularly in office buildings or warehouses, which do not have the advantage of obtaining the necessary moisture from the atmosphere such as outside floors and sidewalks on which the dew falls at night, if not properly protected and kept damp, become prematurely dry and are therefore more or less porous and weak, causing easy abrasion under foot traffic, or what is commonly known as dusting.

Care should be exercised in keeping such floors damp by covering with wet sand, wet hay or straw, for a week or more until the floor has properly hardened. If this has not been done and the floors are found to dust under foot traffic, the following remedy will be found very easy to accomplish, economical and effective.

Wash the floor thoroughly with clean water, scrubbing with a stiff broom or scrubbing brush, removing all dirt and loose particles. Allow the surface to dry, as soon as dry apply a solution of one part water-glass (sodium silicate) of 40° Baume, and 3 to 4 parts of water, the proportion of water depending upon the porosity of the concrete. The denser the concrete the weaker the solution required. Stir well, and apply this mixture with a brush (a large whitewash brush with long handle will be found the most economical). Do not mix a greater quantity than you can use in an hour.

If this solution is sufficiently thin, it will penetrate the pores of the concrete. Allow the concrete surface thus treated to dry. As soon as dry, wash off with clean water using a mop. Again allow surface to dry and apply the solution as before. Allow to dry and again wash off with clean water, using a mop. As soon as the surface is again dry, apply the solution as before. If the third coat does not flush to the surface apply another coat as above.

The sodium silicate which remains on the surface, not having come in contact with the other alkalies in the concrete, is readily soluble in water and can therefore be easily washed off, thus evening up the color and texture of the floor. That which has penetrated into the pores, having come in contact with the other alkalies in the concrete, has formed into an insoluble and very hard material, hardening the surface, preventing dusting and adding materially to the wearing value of the floor.

Natural Gas in 1909 and 1910.—The production of natural gas in the United States in 1909, as ascertained by a joint canvass made by the United States Geological Survey and the Bureau of the Census, is estimated by B. Hill, in charge of this work, under the supervision of D. T. Day, to have been $55,000,000, an increase of only about $359,626 over that of 1908. There were no great changes in the industry during the year, the production continuing to decline in Kansas, and an increase being made in Oklahoma and

in the Caddo field in Louisiana and in Texas. An interesting feature was the supplying of Fort Worth and Dallas from the gas fields of Clay County, Tex. For the year 1910 the total production is estimated at $57,000,000, an increase of about $2,000,000 over 1909. During 1910 a feature of great interest was the development of what promises to be a very large supply of natural gas in the Buena Vista Hills, Kern County, Cal., east of the Sunset-McKittrick oil field. Arrangements were made and practically completed during the year for piping this gas to Bakersfield and other towns in San Joaquin Valley.

Reduction of Selenium or Tellurium. (*Eng. and Mining Jour.*, xc, 1091.)—The reduction of selenium or tellurium oxides to metal by carbon in the presence of soda or other bases is impossible, owing to the reaction between the base and the metalloid, resulting in the formation of selenides or tellurides.

A New Metal-Tempering Process. ANON. (*The Iron Age*, lxxxvi, 1318.)—P. J. A. Douglass, Dartmouth, N. S., has discovered a process for tempering non-ferrous metals. The special advantages claimed are non-corrosiveness, flexibility and a uniform temper. Metals thus treated will take a keen edge and are available for cutlery and all kinds of tools. It is possible to use castings of these metals which are cheaper than forged steel.

Dyeing, Tanning and Vulcanization. W. P. DREAFER. (*J Soc. Dyers and Col.*, xxvi, 268.)—The similarity between dyeing and tanning is pointed out, in that the solution phenomena are comparable and are closely concerned with the colloidal condition. The processes of absorption involved are paralleled in the case of vulcanization.

A New Pyrophoric Cerium and Magnesium Alloy. ANON. (*Brass World*, vi, 331.)—A. Huber of Berlin has produced a pyrophoric alloy by alloying 85 per cent. cerium with 15 per cent. magnesium. When this alloy is heated to a temperature of about 550° C. in a closed muffle furnace and hydrogen gas is passed in and absorbed by the metal, the pyrophoric qualities of the alloy are greatly increased.

A New Platinum Alloy. (*Iron Age*, lxxxvi, 783.)—W. C. Finck, a jeweler of Elizabeth, N. J. has patented a platinum alloy which can be used as a substitute for pure platinum for many purposes and only costs about 3 per cent. as much. It melts at a temperature 600° lower than platinum and does not corrode nor tarnish under the influence of the atmosphere or of acid fumes, but is slightly discolored by surphur. It is stated that it wears as

well as gold and is not distinguishable from platinum when alternated with gold in chains. It is used for diamond mounting and jewelry and it is believed will make good ignition points for spark-plugs and may be available for use in cauterizing instruments and wood-burning tools.

High-Tension Transmission Line Insulators. ANON. (*Electr. World*, lvi, 1127.)—The insulator acts as a condenser and must be designed so that the electric stresses in it are a minimum. When the capacity is large so also is the charging current which, spreading over the insulator, forms the corona, produces streamers, and gives rise to periodic flash-overs. The effect of rain is to increase the capacity of the insulator, and this tends to produce flashes to earth. The theory of these insulators is discussed and practical applications of it are given.

Solubility of Oxygen in Molten Silver. F. G. DONNAN AND T. W. A. SHAW. (*Soc. Chem. Ind. Jour.*, xxix, 987.)—The volume of oxygen absorbed by 10 Gm. of melted silver at 1020° C. and 751 mm. pressure was 20.5 c.c.; a second determination at 1020° C. and 753 mm. gave 20.2 c.c. These figures agree well with Sievert's, and show that the concentration of the oxygen in molten silver is proportional to the square root of the oxygen pressure over a wide range of pressures. From this it is concluded that the oxygen is either physically dissolved as atomic oxygen, or exists in the form of dissolved silver monoxide.

The Effect of Carbon and Carbon Monoxide in Metallurgical Reactions. G. CHARPY. (*Rev. Met.*, vii, 962.)—In studying the effect of pure carbon at high temperatures on iron and allied metals, it is very difficult to eliminate all occluded gases. With the oxides of these metals the temperature of their dissociation affects the results considerably. It is, however, concluded that up to a temperature of 1000° C., pure carbon has no action on the metals of the iron family, or their oxides; that carbon monoxide at the same temperatures carburizes iron, reduces all the oxides of iron and nickel and the higher oxides of manganese, oxidizes metallic chromium and manganese, and has no appreciable action on metallic nickel, manganous oxide and chromium tri-oxide.

A New Vegetable Wax Found in Mexico. ANON. (*Revue Scientifique*, xlviii, 842.)—In the district of North Mexico, where the caoutchouc plant " Guayule " is found, there grows a little plant which the natives call the " candelilla " or little candle, on account of its shape. The whole of the plant except its roots is covered with a wax, which in the United States has been considered as beeswax and has been recognized as superior to car-

nauber wax. Samples of the candelilla wax were sent to a London firm who immediately purchased 50 tons a month of it. The candelilla is found in the southern regions of Mexico, but in an insufficient quantity for commercial purposes. It easily reproduces itself and requires little care. When cut down level with the soil it grows again in one or two years, and is very prolific.

Aluminum-Bronze Coinage. ANON. (*Revue Scientifique,* xlviii, 844.)—The French Coinage Commission reported against an aluminum coinage, as neither aluminum nor its alloys offer sufficient resistance to blows and friction. They recommend aluminumbronze, an alloy of 90 per cent. copper and 10 per cent. aluminum. The coins have the beautiful yellow color of gold and to prevent any confusion the Committee recommend that the coins be pierced with a central circular orifice, which would be a sufficient guarantee against their being mistaken for gold coins.

Structure of Graphitic Cast-Iron. OTTO KRÖHNKE. (*Metallurgie,* vii, 674.)—When cast-iron is transformed into the graphitic condition by corrosion, the ferrite is removed from the pearlite, while cementite and iron phosphide remain unchanged. The graphite retains its position in the mass, but is partly converted into a white or gray substance, graphitite, of unknown composition. White cast-iron does not undergo such a change, as the constituents resist corrosion. Wrought-iron, although containing small quantities of pearlite, does not corrode in this way, the presence of graphite being necessary to produce the requisite electrolytic couples.

Radium Lode in South Australia. D. MAWSON. (*Pharm. Jour.,* lxxxv, 804.)—Radio-active mineral is found at Yudna Mutana, containing carnotite and torbernite, which is a hydrated uranium copper phosphate and this occurrence is unique in Australasia.

Fertilizer Value of Manganese Sulphate. A. CARLIER. (*Biedermann's Zentr.,* xxxix, 859.)—Manganese sulphate was added in the proportion of 44.5 pounds and 89 pounds per acre to grass land. In the first case there was an increase of 0.9 per cent. and in the second of 9.5 per cent. in the hay crop. A few days after the addition of the fertilizer its action became evident as the plot appeared a vivid green. In the case of potatoes and turnips, the crop actually diminished; the potatoes lost 9 per cent. in the first case and in the second, lost 0.6 per cent., with turnips the roots showed 2.5 and 1.0 per cent. respectively less, and the leaves 25 per cent. and 20 per cent. respectively less. These results show that manganese sulphate does not possess the high fertilizer value often attributed to it.

Making Auto Motors and Parts. E. F. LAKE. (*Amer. Mach.*, xxxiv, 95.)—This article gives some methods and machines employed in machining the engine cylinders, piston rods and small levers. Testing and balancing the fly-wheels. The means employed to test the assembled motors, transmissions, rear axles and springs of an automobile. To those interested this article will be found valuable.

Fire Engine Work. F. A. STANLEY. (*Amer. Mach.*, xxxiv, 112.)—This article will repay careful perusal by those interested. It refers to the construction and application of a drill-press device for chucking work of irregular outline for drilling and tapping. They are presented either side up to the tools and can be set easily in any position under the spindle. Some boring, facing, and tapping tools for mounting directly on the end of the spindle are described.

Color Screens on Celluloid Films or Coatings. (Eng. Patent of C. SPAETH, 23,138, Oct. 6, 1910.)—In the preparation of color screens by successively staining portions of a celluloid surface with solutions of different dyestuffs, it is proposed to dilute the solvent used for making the solution more and more for each successive staining; as in this way the previously stained surfaces are not affected by the more dilute solutions. A celluloid film may be coated on each side with a thin layer of rubber and on one of these layers a series of lines is scratched to expose the celluloid surface; the film is now dipped in a solution of 2 Gm. of Victoria Blue in 100 c.c. of absolute alcohol, washed and dried; a second series of lines is scratched on the surface, preferably perpendicular to the first, and the film immersed in a solution of 2 Gm. of Auramine and 1 Gm. of Ethyl Green in 150 c.c. of 80 per cent. alcohol, washed and dried. The remaining rubber coating is washed off the one side of the celluloid, and the film is immersed in a solution of 2 Gm. of Rubin and 1 Gm. of Auramine in 150 c.c. of 60 per cent. alcohol. The resulting screen will consist of blue lines and green and red squares.

Constitution of Troostite. A. McCANCE. (*Engineering*, xc, 905.)—" Troostite " is the micrographic constituent of steels discovered and described by Osmond. Microphotographs of steels show that the carbon content of troostite may vary, and that it should not be considered as finely divided pearlite, although being a transition product, it is a stage in the development of pearlite in the same sense as martensite is, and pearlite may be obtained ultimately from both martensite and troostite. From a discussion of the curves given for the expansion of a bar of steel, for the residual magnetism, for the changes in magnetic intensity on reheating, and for the variation in density on tempering, it is concluded that troostite is amorphous and uncrystallized α-iron which has not

yet attained its crystalline state of ferrite. On re-heating a quenched steel, the first effect is to change the iron to the uncrystallized α-form (troostite) from which the carbon (since it is insoluble in α-iron) is deposited *in situ* as $(Fe_3C)_2$. This is unable to polymerize into $(Fe_3C)_4$ (cementite) and remains in suspension; hence it is concluded that troostite contains carbon in suspension and not in solution. Above 450° C. the α-iron crystallizes as ferrite in low carbon steels, and with increasing polymerization of the carbon compound, the remaining complex mass becomes sorbitic and finally pearlite.

Action of Radium Rays on Colloids. W. P. JORISSEN AND H. W. WONDSTRA. (*Zeit. Chem. Ind. Kolloide,* viii, 8.)—On exposing a ferric oxide solution prepared by digesting ferric oxide with ferric chloride solution and subsequent dialysis, to the radiation from radium bromide contained in thin glass tubes, the authors were able to confirm the statement of Henri and Mayer, that the ferric oxide solution in presence of a quantity of sodium nitrate insufficient alone to cause coagulation, is coagulated when exposed to the radium preparation. Although the ferric oxide solution alone apparently remains unaffected by exposure to the radium bromide, it is in fact rendered more sensitive, for generally it is coagulated by quantities of electrolytes insufficient to cause coagulation of a similar solution which has not been so exposed. The radium rays have no observable similar effect on a silver solution.

Cause of Efflorescences on Mortars and Stones. P. ROHLAND. (*Z. Chem. Ind. Kol.,* viii, 48.)—Efflorescences on mortars, bricks, etc., are caused by crystalloid substances (acids, bases or salts) and not by colloids. The extent of the efflorescence depends partly on the porosity of the mortar, bricks, etc., for in a very porous material the soluble salts may crystallize partly in the interior of the material, whereas with a material of close structure the water, with its dissolved salts, is forced to the surface. Soluble salts may separate quantitatively on the surface of mortar, etc., after hardening. For example, if plaster of Paris be guaged with water containing 0.05 Gm. of copper sulphate in solution, the plaster remains pure white during setting and hardening, but after several hours, the blue copper sulphate crystallizes out on the surface quantitatively.

Influence of Soluble Sulphates on Kaolins and Clays. R. RIEKE. (*Sprechsaal,* xliii, 709, etc.)—The soda-slip casting process has now attained such recognition that the rival theories of plasticity,—one attributing it to the presence of colloids, the other to soluble salts in the clay,—become of commercial importance. The influence of soluble sulphates on the fluidity of slip, and their adsorption by clay, have therefore been examined, and the following

conclusions reached. Most soluble sulphates increase the viscosity of a slip, and therefore barium hydroxide should be added to the slip. The most harmful sulphates are those of calcium, aluminum and the heavy metals. Alkali sulphates stiffen the slip up to 0.1 per cent., then render it more fluid up to 1.0 per cent., and then stiffen it again. Zinc and copper sulphates act in the same way. The curve representing the activity of the salts rises rapidly on small additions of sulphates, but slower on large additions. It is also dependant to some extent on the proportion of clay to water in the slip. Water free from sulphates should be used. Clays absorb sulphates in small quantities, though sometimes the clay absorbs the metallic iron, leaving the sulphate iron to withdraw an alkali metal from the clay, by double decomposition.

Electric Furnaces in Non-Ferrous Metallurgy. J. W. RICH-ARDS. (*Met. Chem. Eng.,* viii, 233.)—The advantages of electric-over blast-furnaces are: They produce purer metal castings and crucible quality alloys, due to the absence of injurious gases. They are efficient for roasting sulphide and arsenide ores, as there is no interference with oxidation. The process of concentrating ores to mats can be better regulated. They are especially valuable for reducing to metal, as there will be less volatilization and fume loss, owing to the smaller volume of combustion gases; moreover a uniform temperature can be maintained throughout and only as high as may be necessary. For roasting ores so as to condense the metallic vapors, zinc for example, heat may be supplied inside the retorts instead of outside, thus increasing the calorific efficiency.

The Constituents of the Active Deposit of Actinium. L. BLANQUIES. (*Comptes rendus,* cli, 57.)—Experiments conducted to prove or disprove the existence of a substance giving rise to Act B. and emitting a rays, did not give irrefutable proof, but: (1) The assumption that this substance exists furnishes a simple explanation of the peculiar form of Bragg's ionization curve for the induced activity of Actinium. (2) The assumption accounts for the difference in the law of disappearance of the scintillations for polonium as compared with that of the active deposit of actinium. (3) The initial drop in the decay curve supports the above hypothesis. (4) The hypothesis explains the observation of Geiger and Marsden that 10 per cent. of the scintillations produced by the active deposit of actinium are double.

UPON THE CONSTRUCTION OF THE WHEATSTONE BRIDGE FOR ELECTRICAL RESISTANCE THERMOMETER.

BY

C. F. MARVIN,

Weather Bureau.

THE electrical resistance thermometer is now widely recognized as one of the most available and best of the many devices that may be employed as an accurate secondary standard for the measurement of temperature, and methods for its easy manufacture are greatly to be desired.

The present ultimate standard scale of temperature is Lord Kelvin's so-called thermodynamic scale, or the almost identical scale of the constant volume hydrogen thermometer. It is well understood that other scales, such as one obtained from the expansion of mercury-in-glass, or from the temperature variation in resistance of some metal, or from the potential change in some thermo-junction, or from any other temperature effect, all differ from each other and from the standard scale. Whenever, therefore, any one of the secondary thermometers is employed, its readings must generally be reduced to the gas scale of temperature by some more or less elaborate conversion tables or sets of corrections. The question of the interrelation of different thermometric scales is a very extensive one, and we point out here simply the essential fact that they are all different.

The purpose of the present paper is to describe definite and exact methods by which manufacturers of electrical instruments can construct resistance thermometers so as to indicate temperatures on the gas scale directly and thus avoid the necessity of the troublesome conversion tables commonly employed.

Resistance thermometers can already be obtained, provided with direct reading temperature scales, but these are produced by a sort of cut and try process that is not only tedious in its application, but the results are not so certain or so uniformly exact as those obtained by the method we wish to describe.

The change in resistance of electrical conductors with temperature is rarely or never exactly proportional to the change in temperature. It is therefore generally necessary that the scale on the instrument from which the true temperature is to be read, must be one of unequal parts, or the steps in resistance corresponding to the intervals on the scale must be unequal. In the instruments heretofore made it is often customary to resort to both these expedients in order that readings shall be expressed directly in standard temperatures; that is, the subdivisions of the scale are made unequal and the steps in resistance corresponding to successive intervals on the scale are also made unequal. Now it is a very easy matter to subdivide a scale into a given number of sensibly equal parts, but it is a very difficult or nearly impossible thing to subdivide a scale into progressively unequal parts that shall correspond accurately to some complex law of inequality. So, likewise, it is a very easy thing to make up numerous steps or intervals of resistance all sensibly equal to each other, but progressively unequal steps in resistance can be produced only by the expenditure of time and tedious hand work.

The methods of construction herein described enable one to make up a resistance thermometer in which the subdivisions of the scale are equal and so also are the steps of the variable resistance, nevertheless the readings are in standard temperature units subject only to certain very small errors that in general are even smaller than the customary unavoidable errors of manufacture. The studies thus far have been restricted chiefly to ordinary atmospheric ranges of temperature, say from — 40 to + 60° C. The mathematical relations, however, are general and admit of application to widely different conditions.

The order of accuracy aimed at may be put at, say, about one-tenth of a degree; that is, discrepancies of this amount may be tolerated. The method, therefore, can be employed in the construction of a large class of thermometers, such, for example, as are used in meteorological observations, in many manufacturing processes, and for commercial purposes generally where moderate ranges of temperature at approximately atmospheric conditions suffice.

In the new construction we simply avail ourselves of certain interesting mathematical relations between the equations representing the changes of resistance of the given thermometer with temperature and the equations for the bridge, according to the particular arrangement of resistances employed.

The close mathematical similarity between the equations referred to was pointed out for a particular case in a previous paper.[1] More exact data than was originally available have recently been obtained relative to the variation of the resistance of nickel over ordinary atmospheric conditions of temperature, and, in the present paper, we shall develop the mathematical relations referred to more fully and extend their application to the general problem of constructing bridges and indicating devices to give gas scale temperatures directly by means of resistance thermometers made of various kinds of material.

The relation between the temperature and resistance of nickel, of the quality ordinarily supplied by the customary dealers in the form of wires, can be quite accurately represented over a range of temperature, say, from -40 to $+70°$ C. by a logarithmic equation of this form:

$$Log.\ R = a + bt - ct^2 \qquad (1)$$

The term in t^2 is wanting, that is c is zero for some specimens of nickel, but in most cases, as shown by the wires thus far examined, the t^2 term must be retained, although the value of c is very small; that is, for the range of temperature considered, the temperature resistance curve can be represented with sufficient exactness by a logarithmic equation of the second degree.

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[1] Note on the relation between the temperature and resistance of nickel. C. F. Marvin, Phys. Rev., vol. xxx, No. 4, Apr. 10, 1910, pp. 523–528.

Table I gives equations for several specimens of nickel wire and ribbons, and also for the purposes of comparison the equation of one of the platinum thermometers, No. 478, used by Messrs. Waidner and Burgess [2] at the Bureau of Standards in studies of platinum thermometry.

In each of the thermometers, Nos. 39 to 52, a small length of manganin wire was joined in series with the nickel, in order to slightly lower the temperature coefficient and thereby be able to reproduce it at any future time by the use of wire from new

TABLE I.

EQUATIONS FOR NICKEL RESISTANCE THERMOMETERS FROM DIFFERENT STOCK, AND FOR PLATINUM THERMOMETER B.S. No. 478; TEMPERATURE RANGE FROM −40° to +60° C.

Equation for Nickel:—$Log. R = a + bt − ct^2$
Equation for Platinum:—$R = a + bt − ct^2$

Thermometer number	R at 0° observed	a	bt	ct²
	ohms.			
Spiral I....................	10.668	1.02806	.00211t	.0000220t²
Spiral II...................	2.129	0.32818	.00206t	.0000209t²
Spiral IIa..................	2.538	0.40449	.002140t	.0000028320t²
Spiral III..................	12.506	1.09712	.002176t	.0000028354t²
Conical receiver	26.171	1.41782	.001879t	.0000020997t²
Silver block receiver	31.073	1.49238	.001876t	.0000017599t²
Therm. No. 39..............	93.190	1.96938	.001542t	.0000011112t²
Therm. No. 41..............	93.334	1.97004	.001516t	.0000010116t²
Therm. No. 43..............	93.156	1.96925	.001538t	.0000010663t²
Therm. No. 51..............	93.223	1.96952	.001517t	.000000989t²
Therm. No. 52..............	93.184	1.96930	.001534t	.0000010131t²
Pt. therm., B. S. No. 478......	5.15665	5.15665	.0202755t	.0000030101t²

Spiral III, Quadratic equation, $R = 12.506 + 0.06252t + 0.000069586t^2$

stock of nickel, which might alone have a lower or higher coefficient than the old stock.

Table II gives the difference, observed minus computed resistance, obtained by the use of the equations given in Table I. To simplify the tabulation a small correction has been applied to each observed value if necessary, in order to bring the temperature to the nearest whole degree and thus avoid the presence of small fractions of degrees.

Over the range of temperature considered, it follows from the data that the curve representing the change of resistance of nickel with temperature is *concave* upward. The curve for pure plati-

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[2] Bulletin of the Bureau of Standards, vol. vi, No. 2, p. 156, 1910. Reprint No. 124.

num is *convex* upward, and, as is well known, the resistance changes very closely in accordance with the parabolic law over a very great range of temperature, probably from far below zero to 1000° C. more or less. It is immaterial for our present purposes what particular equation is employed to express the temperature resistance data for any particular thermometer.

A careful examination of the data for thermometers No. 39, 41, 43, 51 and 52 shows that, although these instruments are very nearly identical, yet the differences between them, both in the absolute resistance at zero and the law of change, are greater than seem necessary. The difference in the resistances at zero

TABLE II.

COMPARISON OF OBSERVED MINUS COMPUTED RESISTANCE OF NICKEL THERMOMETERS MADE FROM DIFFERENT STOCK; DEVIATIONS EXPRESSED IN TEMPERATURE.

Temp., °C.	Ribbon spirals				Coni-cal rec.	Sil-ver block	Similar therms.				
	I	II	IIa	III			No. 39	No. 41	No. 43	No. 51	No. 52
−36							+.03	−.03	−.02	−.04	−.03
−26			−.01	−.04	+.03	±.00	−.01	+.01	±.00	+.01	+.01
−18			−.02	−.00	+.01	+.02	±.00	±.00	±.00	±.00	±.00
−10			−.04	−.02	−.04	−.02	−.05	±.00	±.00	+.01	±.00
0	±.00	−.01	±.00	±.00	±.00	±.00	±.00	±.00	±.00	±.00	+.01
11	−.02		−.06	−.05	−.05	−.05	−.03	−.06	−.05	−.05	−.03
22							−.02	−.06	−.06	−.08	−.07
33	−.06	−.05	−.25	−.08		−.03	+.05	±.00	−.02	+.03	−.03
45	−.10		+.06	±.00		+.05					
48	−.08	+.03			+.07		+.28	+.15	+.16	+.14	+.14
54	−.02	+.05									
60		−.02	+.35	+.29		+.17					

in the extreme is nearly 0.2 per cent., and corresponding differences at other temperatures are apparent. If it is not practicable to duplicate thermometers of a specified type more accurately than shown in these data, then it is impracticable to make thermometers that are strictly interchangeable, or to use a large number of thermometers on one bridge without introducing important errors. Of course corrections for the individual thermometers can be worked out if necessary.

Upon the completion of the numerous observations and mathematical computations required in preparing the data given in Tables I and II, it became apparent that in almost every case the computed value by the logarithmic equation was systematically too high at moderate temperatures, and, especially, was too low

at the highest points observed. This led me to try some other equations on one of the spirals, viz., III, and it was found that the simple parabolic equation $R = a + bt + ct^2$ (see Tables I and II) gave values in still closer agreement with the observations than the logarithmic equation. This form of equation will doubtless be used in future work, but the labor of recomputing all the old observations has not seemed necessary.

We shall pass at this point to the question of the bridge itself, and shall consider the equations and points of advantage of the

FIG. 1.
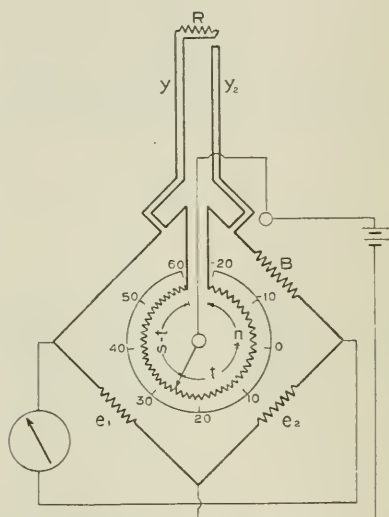
$$\frac{R + 2y_1 + s - t}{B + 2y_2 + n + t} = \frac{e_1}{e_2} \qquad R = B + n - s + 2t, \text{ when } e_1 = e_2 \text{ and } y_1 = y_2$$

several well-known methods of arranging the connections. Four of these are shown diagrammatically in Figs. 1–4, and help to fix the ideas we have indicated a scale of temperature from — 20° to + 60° C. with the thermometer or variable resistance in series with the bridge wire, shown here in circular form with a radial arm carrying the slider. This wire and scale may be made up in a great variety of ways customary to the art in such cases, the only stipulation being that the scale shall be one of sensibly equal parts, and that the portions of the wire comprised between successively equal spaces on the scale shall have sensibly equal

resistances throughout. This arrangement constitutes the customary connections used with the platinum thermometer with dummy leads for compensation; e_1 and e_2 are equal ratio coils, and the equation reduces to the form $R = B + n - s + 2t$. This linear equation gives the so-called platinum scale of temperatures, which requires changing corrections from point to point along the scale to reduce the readings to the gas scale. The four-wire system of compensation leads may sometimes be objectionable as when the thermometers are placed at considerable distances

FIG. 2.
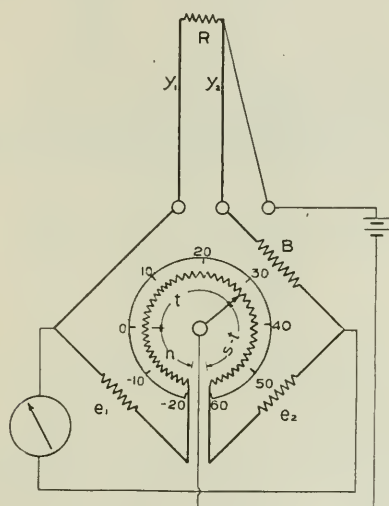
$$\frac{R + y_1}{B + y_2} = \frac{e_1 + n + t}{e_2 + s - t} \qquad R = \frac{A + Mt}{N - t}$$

from the indicator. Other systems of connections are possible, that require only three leads, one of which is simply a battery connection.

In all cases, however, when the platinum thermometer is used on work requiring great precision, the Fig. 1 bridge is doubtless better than any other, in which case the direct temperature scale is dispensed with, and even the slide wire itself is best replaced by some special form of rheostat capable of adjusting the resistance with the required precision.

Fig. 2 represents the resistance thermometer at R joined by

the well-known system of three wire compensation leads, y_1 and y_2 and a battery wire. The balancing coil is at B, and e_1 and e_2, either equal or unequal, are extension coils in series with the bridge wire.

Let $R =$ the resistance of the thermometer in ohms at the nominal temperature t indicated by the bridge scale when the bridge is balanced.
Let $y_1 = y_2 = y =$ the resistance of the lead wires in ohms.
Let $B =$ the resistance of the balancing coil in ohms.

We have assumed for purposes of illustration that the scale extends both above and below zero and comprises a range of temperature from — 20 to + 60° C.

Let $n =$ the number of units below zero on the scale.
Let $s =$ the number of units above zero on the scale.
Let e_1 and e_2 be the resistance of the extension coils. (It is simplest in computations to express the resistance of the extensions in temperature units; that is a unit equal to the resistance of one degree of the bridge wire.)

The ratio of the bridge arms then becomes:

$$\frac{R + y_1}{B + y_2} = \frac{e_1 + n + t}{e_2 + s - t}$$

$$R = B \frac{e_1 + n + t}{e_2 + s - t} + \frac{e_1 + n + t}{e_2 + s - t} y_2 - y_1.$$

If the thermometer leads, y_1 and y_2, are equal, as is most easily the case in practice, we see at once from the above equation that the effect of the leads is not fully compensated for, except in one or two possible cases. At some particular temperature it may be possible for the coefficient of y_2 to be unity, whence we have perfect compensation for that particular condition only. Or y_1 and y_2 being unequal, we get compensation at some one temperature if y_2 multiplied by its coefficient equals y_1. The compensation is therefore imperfect in this method of wiring, and we shall retain the expression for lead resistances in the bridge equation, which, upon rearranging the terms becomes

$$R = \frac{B (e_1 + n) - y (e_2 - e_1 + s - n) + (B + 2y) t}{e_2 + s - t} . \tag{2}$$

This is the general equation of the bridge, and takes into account the resistance of the lead wires, $y_2 = y_1 = y$. But we

have assumed that y is a constant, that is, we neglect, as we may, the small nearly compensated effects due to temperature changes of resistance in the leads. The second member of the equation, therefore, contains only one varible term, namely t. For com-

FIG. 3.

$$\rho = \frac{ar\,(s + c - t)}{r + s + c - t}$$
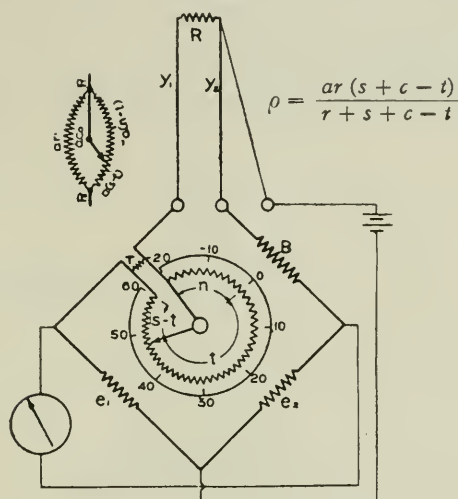
$$\frac{R + y_1 + \rho}{B + y_2} = \frac{e_1}{e_2} \qquad R = \frac{A + Mt}{N - t}$$

putation the equation may be reduced to the following simple form:

$$R = \frac{A + Mt}{N - t}. \tag{3}$$

in which,

$$\begin{aligned}
A &= B\,(e_1 + n) - y\,(e_2 - e_1 + s - n) \\
M &= B + 2y \\
N &= e_2 + s
\end{aligned} \tag{3a}$$

Before showing how the general equation may be utilized in designing the bridge, we shall examine the other methods of using the bridge shown in Figs. 3 and 4.

In Fig. 3 the bridge wire is joined in one arm of the bridge in series with the thermometer. The wire is provided with a fixed shunt r, and the slider is joined in as a second shunt, which

in the simplest case may be given a very low resistance. We shall form the equations of the shunt, however, assuming that the slider arm is itself a definite resistance. This will retain the position of this term in the final equation, when the term can be evaluated according to circumstances. In adopting this form of construction it will be necessary to employ some form of wire and slider that will have sufficiently small contact resistance to meet the requirements, which demands far better contacts than are necessary in Fig. 2. There are very great advantages in the case of Figs. 3 and 4, and it may prove worth while to over-

FIG. 4.

$$\rho = \frac{ar(s + c - t)}{r + s + c - t}$$

$$\frac{R + y_1}{B + \rho + y_2} = \frac{e_1}{e_2} \qquad R = \frac{A + Mt}{N + t}$$
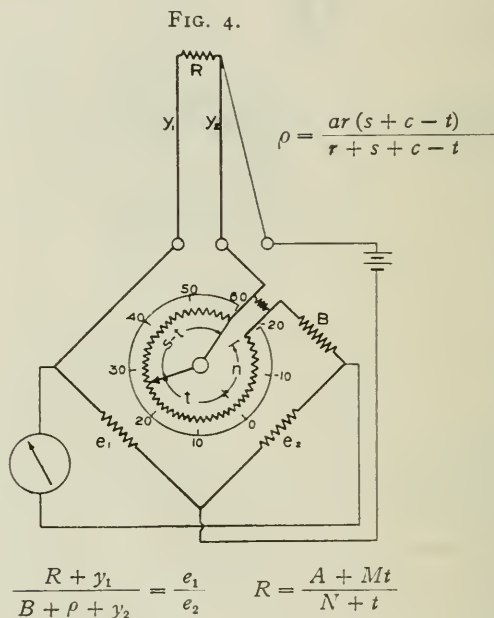
come the obvious difficulties due to contact resistances at the slider. As before, B is the balancing coil and e_1 and e_2 are equal ratio coils of appropriate magnitude.

Following the same notation as before we get

$$R = \frac{e_1}{e_2} B - \rho + \frac{e_1 y_2 - e_2 y_1}{e_2},$$

where ρ is the resistance of the shunted rheostat. If e_1 equals e_2 and y_1 equals y_2, the whole term containing y_1 and y_2 be-

comes zero at all temperatures, whence we realize complete compensation for the leads. The resistances in all the arms of the bridge remain constant, giving, therefore, constant galvanometer sensibility.

The several components constituting the shunt are indicated at one side, and are made up of the following connectors between P_1 and P_2:

1. The shunt r; resistance $= ar$, in which a is the resistance of one unit of the bridge wire and r is a number representing the bridge wire units in the shunt.
2. Part of the wire $s - t$; resistance $= a(s - t)$.
3. Slider arm and contact resistance; assume resistance $= ac_0$.
4. Part of the bridge $n + t$; resistance $= a(n + t)$.

Numbers 3 and 4 are in parallel with each other and the two are in series with No. 2.

Let $ac =$ the joint resistance of Nos. 2 and 3. Then

$$ac = \frac{ac_0(n + t)}{c_0 + n + t} \tag{4}$$

The whole resistance of the shunted connection becomes

$$\rho = \frac{ar\left(\dfrac{c_0(n + t)}{c_0 + n + t} + s - t\right)}{r + \dfrac{c_0(n + t)}{c_0 + n + t} + s - t}$$

It is obvious that so long as c_0 has an appreciable magnitude, then ρ is a complex function of the form

$$\rho = \frac{a' + b't - t^2}{m' + n't - t^2}\, ar.$$

Retaining the simple expression ac for the joint resistance of Nos. 2 and 3, and substituting the value of ρ in the equation of the bridge we get an equation of the same form as (2) with some differences in the constants, viz.,

$$R = \frac{B\,(r + s + c) - ar\,(s + c) + (ar - B)\,t}{r + s + c - t}\,. \tag{5}$$

If the slider arm of the shunted rheostat is given some sensible resistance, then c becomes a complex function of t, and R becomes a still more complex function of this form:

$$R = \frac{A' + M't + pt^2}{N + Qt - t^2}.$$

Nothing is to be gained by this great complexity in the present problem, and we shall therefore avoid all of it by reducing the resistance in the slider arm to the smallest practicable amount; that is $ac_0 = o, \therefore c = o$ and (5) reduces to

$$R = \frac{A + Mt}{N - t} \qquad (6)$$

in which

$$
\begin{aligned}
A &= B\,(r + s) - ars \\
M &= ar - B \\
N &= r + s
\end{aligned}
\qquad (6a)
$$

While the form of (6) is identical with (3), the constants A, M and N represent different elements of the bridge.

In the case shown in Fig. 4 we have the shunted rheostat in series with B. The bridge ratios are

$$\frac{R + y_1}{B + y_2 + \rho} = \frac{e_1}{e_2}$$

and since $e_1 = e_2$ and $y_1 = y_2$,

$$R = B + \rho.$$

Making the resistance of the slider arm zero as before we get

$$\rho = \frac{ar(n + t)}{r + n + t}$$

in which we note that t is positive and n takes the place of s.

We have in this case for the final equation,

$$R = \frac{A + Mt}{N + t} \qquad (7)$$

in which

$$
\begin{aligned}
A &= B\,(r + n) + arn \\
M &= B + ar \\
N &= r + n
\end{aligned}
\qquad (7a)
$$

From all the foregoing, it follows that the bridge equation is either a linear equation or an equation of the form

$$R = \frac{A + Mt}{N \pm t}. \qquad (8)$$

The three constants, A, M and N, are entirely arbitrary in so far as the mere fabrication of the bridge is concerned, and can be given almost any values we please. Therefore, by exercising a proper choice in the manner of connecting up the bridge and of the resistances in the arms, that is, the values of the constants A, M and N, the bridge scale can be fitted to almost any kind of resistance thermometer, whether its resistance changes with temperature by a linear law or according to some curve, either convex upward or downward. Indeed, if it seemed desirable, the greater complexity resulting from placing definite resistance in the slider arm of the shunted rheostat could be availed of, and the bridge scale could thus be adapted to highly complex laws of variation in resistance in the thermometer arm of the bridge.[1]

A few examples will suffice to illustrate how easily a bridge can be made up to fit a given thermometer.

EXAMPLE I.—Calculations of the elements of an ordinary slide wire bridge; Fig. 2; nickel ribbon, Spiral III; quadratic equation:

$$R = 12.506 + 0.06252t + 0.000069586t^2.$$

We take three values of R from this equation at temperatures selected arbitrarily within the range of the bridge scale of temperature, say, for example, at $-10°$, $+20°$ and $50°$. A least square computation involving several values of R might be resorted to, but the slightly closer coincidence of curves possibly secured by such a course does not justify the greatly increased labor.

$$\text{At} - 10° \ R = 11.888$$
$$\text{At} + 20° \ R = 13.784$$
$$\text{At} \quad 50° \ R = 15.806$$

Introducing these values in the bridge equation,

$$RN - Rt = A + Mt,$$

and solving we get,

$$R = \frac{11917.1 + 47.069t}{952.86 - t}.$$

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[1] See note at end of article.

By the aid of equations $(3a)$, remembering that $n = 20$, $s = 60$, and assuming that the lead resistance $y = 0.05$ ohms, we find:

$$B = \text{resistance of balancing coil} = 46.969 \text{ ohms}$$

$$\left.\begin{array}{l} e_1 = 234.47 \\ e_2 = 892.86 \end{array}\right\} \text{ temperature units on the bridge wire.}$$

If we make the slide wire side of the bridge have the same average resistance as the thermometer and balancing coil say 60.853 ohms, we find:

Whole bridge scale $= n + s = \quad 80 \quad$ temperature units $= \quad 4.032$ ohms
$e_1 = \quad 234.47$ temperature units $= 11.818$ ohms
$e_2 = \quad 892.86$ temperature units $= 45.003$ ohms

Total $= 1207.33$ temperature units $= 60.853$ ohms

that is, each unit of the actual bridge wire must have a resistance of 0.0504 ohms, a result easily controlled, if necessary, in the present case by a shunt across the slide wire proper.

The residual errors of the indications of such a bridge and thermometer, including effects of lead resistance, are less than 0.04 of a degree over the whole range of the scale, except at the extreme ends.

EXAMPLE 2.—Calculation of elements of bridge for thermometer No. 39, using shunted slide wire in series with thermometer; Fig. 3; equal ratio coils:

TABLE III.

ACTUAL MINUS INDICATED TEMPERATURES BY THE BRIDGES OF EXAMPLES 1, 2 AND 3.

Temp. °C.	Corrections spiral III slide wire		Corrections therm. No. 39; shunted wire		Corrections Plat. therm. B. S. No. 478; shunted wire	
	Resist. ohms	Temp.	Resist. ohms	Temp.	Resist. ohms	Temp.
− 20	+.001	+.02	+.013	+.04	−.00018	−.009
− 10	0	0	0	0	0	......
0	−.001	−.02	−.006	−.02	−.00001	......
+ 10	−.001	−.02	−.004	−.01	−.00001	......
20	0	0	0	0	0	......
30	+.001	+.02	+.004	+.01	0	......
40	+.001	+.01	+.006	+.02	0	......
50	0	0	0	0	0	......
60	+.007	+.10	−.016	−.04	−.00001	......

The value of A, M and N are computed as in example 1. Then, with equations (6a) we get,

B = resistance of balancing coil .... = 114.29 ohms
ar = resistance of shunt .... = 319.98 ohms
a = resistance of wire per degree of scale = 0.3270 ohms
$a(n+s)$ = resistance of whole scale............ = 26.161 ohms.

As we have already stated, there are great advantages in this arrangement in that the effects of lead resistance are perfectly compensated by a system of two equal leads and a third wire for battery, and the resistance in the arms of the bridge remain constant contributing to constant sensibility of the galvanometer. Some difficulties of construction are recognized in order to satisfactorily overcome questions of contact resistance on the bridge wire, and the exactness necessary in the adjustment of the resistance of the slide wire itself.

We shall give but one more example to illustrate the application in the case of platinum thermometers and to wires with a temperature resistance curve concave downwards.

EXAMPLE 3.—Bridge for platinum thermometer B. S. 478; shunted slide wire in series with the balancing coil; Fig. 4; equal ratio coils, and effects of lead resistance wholly eliminated with three wire leads:

B = resistance of balancing coil = resistance of thermometer computed from bridge equation at lowest temperature of scale .... = 4.7500 ohms
ar = resistance of shunt .... = 135.47 ohms
a = resistance of slide wire per degree of scale...... = 0.02040 ohms
$a(n+s)$ = resistance of whole scale..................... = 1.63184 ohms

In the absence of other data, this thermometer is taken to illustrate the application to platinum thermometers, but its resistance is much too small to warrant its use in the manner contemplated; that is, in most practical cases, a thermometer of much higher resistance could just as well be used and would give better results.

Table III gives the temperature errors resulting from the use of the bridge made up in accordance with the mathematical theory set forth. These residuals are simply the actual resistance of the thermometer (computed by the logarithmic, quadratic, or other

equation, assumed to exactly represent the change of resistance with temperature) minus the resistance computed by the bridge equation, the differences for greater clearness being expressed in both resistance and temperature units. Those familiar with bridge constructions will recognize that the residuals introduced by the mathematical relations employed are mostly of a much

FIG. 5.

$$(L) \; Log. \; R = a + bt - ct^2$$
$$(P) \quad R = a' + bt + ct^2$$
$$(B) \quad R = \frac{A + Mt}{N - t}$$
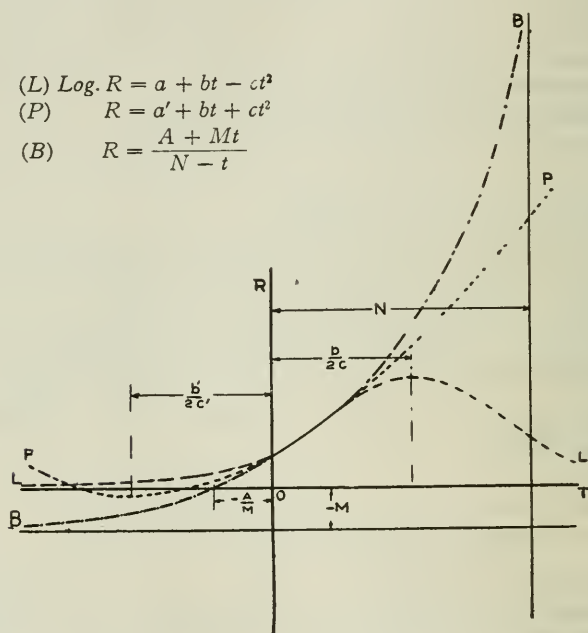
smaller magnitude than the unavoidable errors of adjustment of the resistances and elements of a bridge.

It may be easily shown that the customary methods of constructing indicators for resistance thermometers by the use of a differential galvanometer are fully comprised within the scope of the mathematical analysis herein employed and resistances that will give direct reading temperature scales for such instruments can be computed in much the same manner as illustrated for bridges.

NOTE. It may seem in the foregoing that we actually use the bridge equation

$$R = \frac{A + Mt}{N \pm t}$$

in preference to any other for expressing the relation between the temperature and resistance of the thermometer we employ. This of course can be done and the constants can be computed directly from the temperature and resistance measurements on the thermometer. Such a procedure should, however, be restricted to a relatively narrow range of temperature. Experience, moreover, indicates that the parabolic and logarithmic equations represent the relations between the temperature and resistance of both platinum and nickel over a considerable range of temperature better than the bridge equation. The general character of the several curves for nickel thermometers are shown in Figure 5. The methods of Analytical Geometry readily indicate that the bridge equation

$$R = \frac{A + Mt}{N \pm t}$$

is the equation of a rectangular hyperbola. The asymptotes are parallel to the axes at distances $\pm N$ and $\mp M$ according as the sign in the denominator is $-$ or $+$.

A Search For Potash.—The amounts appropriated for the work of the United States Geological Survey for the fiscal year ending June 30, 1912, include an item of $40,000 " for chemical and physical researches relating to the geology of the United States, including researches with a view of determining geological conditions favorable to the presence of potash salts." It is understood that one-half of this appropriation will be devoted to the potash exploration.

Borax in the United States; Mines All in California.—California produces all the borax mined in the United States and is now supplying nearly all the domestic demand. The principal mine is in the Death Valley region, in Inyo County. Another mine is in Los Angeles County.

The mineral mined is colemite, or borate of lime, most of which is shipped crude to Alameda, Cal., or Bayonne, N. J., for refining.

About half the product is consumed in enameling kitchen ware, but new uses for borax are found every year.

A leaflet on the production of borax in 1909, by Charles G. Yale, has just been published by the United States Geological Survey.

American Society of Mechanical Engineers.—The sixty-third meeting of the Society will be held in Pittsburg, Pa., from May 30th to June 2d, inclusive. The Society has not met in that city since 1884.

An executive committee consisting of E. M. Herr, Chairman, George Mesta, J. M. Tate, Jr., Chester B. Albree, D. F. Crawford, Morris Knowles and Elmer K. Hiles, Secretary, will have charge of the Pittsburg meetings. It is expected that from 300 to 400 members and ladies will be in attendance. There will be professional sessions when papers will be read and discussed. There will also be inspection trips through the leading local industrial establishments besides automobile trips through parks, a visit to Carnegie Institute, Memorial Hall, etc.

The headquarters of the Society are in New York City and Col. E. D. Meier of St. Louis is President this year.

Modern Abrasives Harder Than the Old Ones.—Carborundum and alundum are among the latest of modern abrasives. They are made at Niagara Falls by means of the electric power generated by the cataract. Another new abrasive made there is aloxite, which is used for grinding steel tools. The manufacturers state that it does not greatly heat the tools nor draw their temper. Samite, another new abrasive made at the same place, is used for cutting or abrading aluminum. Its cutting surface does not glaze or fill when it is used on aluminum or other fibrous metals.

STATISTICS FOR 1909.—The United States Geological Survey has published a pamphlet by W. C. Phalen on the production of abrasive materials in 1909, giving statistics of the output and value of burrstones, millstones, grindstones, oilstones, corundum, emery, pumice, and other natural abrasives for that year, and of the artificial abrasives carborundum, alundum, and crushed steel. The pamphlet is an advance chapter from the Survey's volume entitled "Mineral resources of the United States, calendar year, 1909."

Decomposition of Cyanides in the Soil. H. KAPPEN. (*Frühlings Landw. Zeit.,* lix, 19.)—The decomposition of calcium cyanimide in the soil can be caused by inorganic catalysis, though the co-operation of micro-organisms is also possible, and it is impossible at present to distinguish between the action of the two factors. Different soils behave very differently towards cyanimide, probably because in one soil the decomposition is mainly caused by chemical agencies and in another soil by biological effects. Extended experimental studies have shown that certain metallic hydroxide gels, particularly those of manganese and iron, act catalytically in promoting the conversion of cyanimide into carbomide. Silica and alumina gels and the other silicate gels, assumed to exist in soil, have no influence.

THE POLARIZATION OF RÖNTGEN RAYS FROM AN ANTICATHODE OF SILVER.

BY

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THE discovery of the polarization of Röntgen rays was made after a consideration of the ether pulse theory: for this theory led investigators to expect a greater intensity of the rays in a direction at right angles to the cathode stream than in the direction of that stream. C. G. Barkla,[1] from a series of experiments on secondary rays concluded that the primary beam is partially polarized. H. Haga,[2] by use of the photographic method, decided that no polarization of the primary rays exists; but J. Herweg,[3] by use of the same method, came to an opposite conclusion.

W. R. Ham,[4] by use of the ionization method and direct experiments on the primary rays, not only showed that the intensity of the rays is a maximum in a direction at right angles to the cathode stream, but that the intensity decreases symmetrically on either side of this plane.

Dr. Ham's experiments were made on Röntgen rays from an anticathode of lead. From his data we should expect polarization of rays from other metals. Also from his results on the absorption of these rays by silver and tin we should think that there is a difference in the polarization of rays from silver as compared with those from lead and that those from silver are polarized to a greater extent.

Therefore the aim of the following investigations has been,—

1. To learn if the rays from silver be polarized.

2. To learn if the polarization differ from that of the rays from lead,

3. and if so, to what extent and in what manner.

[1] C. G. Barkla, Phil. Trans. A., 204, p. 467.

[2] H. Haga, Ann. d. Phys., vol. xxviii, p. 439.

[3] J. Herweg, Ann. d. Phys., vol. xxix, p. 398, 1909.

[4] W. R. Ham, Phys. Rev., vol. xxx, No. 1, Jan., 1910.

ARRANGEMENT OF APPARATUS.

The apparatus used was practically the same as that used by Dr. Ham. The arrangement for testing the Röntgen rays for polarization, which was the most important part of the apparatus, is shown in Fig. 1. A is the tube constructed with windows W, W, etc., each cut from the same sheet of glass of uniform thickness to eliminate the error that would arise from unequal absorption by the walls of an ordinary X-ray tube. B is a side tube containing the cathode K. The secondary rays that originate in it are cut off by thick lead shields. The two electroscopes E_1, E_2,

FIG. 1.
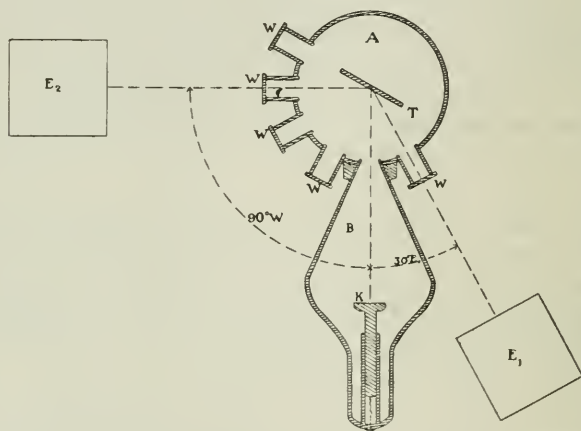
were of the ordinary type for this kind of work. They were charged to a potential of about 340 volts by means of a battery of dry cells, and their discharges read by means of micrometer microscopes.

Another type of tube,[5] used during the early part of the experiment, was constructed from a selected glass cylinder of very nearly uniform thickness. Hereafter we shall call the tube just described No. 1 and the tube with windows No. 2. The target T, one side of which is lead and the other silver, is carefully balanced on a post at the centre of the tube.

The general arrangement of the apparatus is shown in Fig. 2. S, S, are the terminals of a Holtz machine, motor driven. Near

[5] See article by W. R. Ham, Phys. Rev., No. 1, Jan., 1910, Fig. 2a.

the positive terminal is a set of points connected to ground. The negative terminal is connected to the tube and to an air condenser which is in series with a Thompson electrostatic voltmeter. The voltmeter and tube are connected to ground.

PROCEDURE.

The two electroscopes were first tested over long periods of time for rates of natural leak. Then their relative rates of discharge were obtained. This was done at first by placing them side by side about four metres from an ordinary X-ray tube and taking their discharges. Later in the experiment they were placed opposite the two windows at 30° E. and 30° W. of the

FIG. 2.
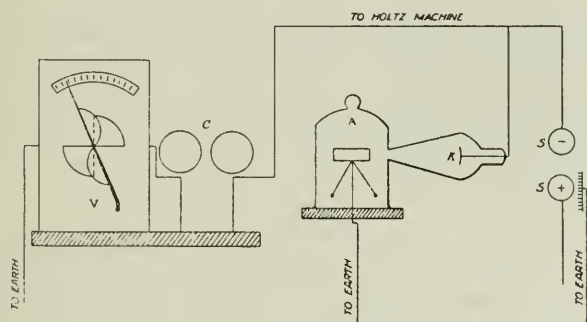
cathode stream. The target was placed perpendicular to the cathode stream and hence the absorption within the target was necessarily the same for both sets of rays. Since the rays that reached the electroscopes made equal angles with the cathode stream the intensities of the two beams should be equal. Therefore the rates of discharge had to depend upon the discharge constants of the electroscopes. As a check on these readings the positions of the electroscopes were reversed but, no change being noticed, the one position was used thereafter. A sample set of readings for determining the relative rates of discharge is given in Table I.

The electroscopes were tested after each set of readings, and it was found that the ratio of the rates of natural leak and the ratio of the rates of discharge were nearly the same. In fact the leak was so small and of such a nature as to cause no error

if neglected. Whenever a leaf was changed the ratio of the rates had to be redetermined.

To determine the relative intensities of Röntgen rays in directions of 30° E. and 90° W. of the cathode stream the electroscopes were placed at equal distances from the axis of Tube

TABLE I.

No. 1 at 30° E.	No. 2 at 30° W.	Ratio No. 2 / No. 1	No. 1 at 30° E.	No. 2 at 30° W.	Ratio No. 2 / No. 1
75.5	84.7	1.121	60.8	68.6	1.126
65.6	74.9	1.141	73.6	84.6	1.149
70.8	80.9	1.143	71.4	80.7	1.130
71.7	80.8	1.136	70.8	80.1	1.131
69.3	78.8	1.137	76.0	84.4	1.115

No. 1. The normal to the target bisected the angle between the electroscopes. No attempt was made to determine the absolute potential at which the rays were generated. Readings were taken on the voltmeter so that a comparison could be made of the polarization of rays from a lead target with the polarization of those from a silver target under exactly the same conditions.

TABLE II.

	No. 1 at 30° E.	No. 2 at 90° W.	Ratio No. 2 / No. 1	No. 1x Ratio	Per. cent. change in intensity	Reading of voltmeter
Lead..............	54.6	72.3	1.14	62.2	13.9	30
	64.1	83.1	1.14	73.1	12.6	28
	65.2	89.7	1.14	74.4	17.0	28
	57.6	76.3	1.14	65.7	14.0	35
	61.5	83.9	1.14	70.2	16.3	34
	42.1	58.2	1.14	48.0	17.5	25
Silver..............	68.3	90.9	1.14	77.8	14.4	36
	65.1	87.6	1.14	74.2	15.3	35
	65.6	89.7	1.14	74.7	16.8	28
	68.2	84.4	1.14	69.7	17.4	27
	62.5	87.4	1.14	71.2	18.5	28
	61.7	86.3	1.14	70.3	18.5	28

A set of readings was taken with rays from lead; then the target was swung around and a set taken using the silver side of the target. A few of the readings and calculated polarizations are given in Table II.

Because it was known that the cylinder from which the tube was constructed was not quite uniform in thickness the experiment was continued with Tube No. 2. Since this tube was pro-

vided with uniform windows and since all rays except those from the two windows in use were screened off, the data is more reliable.

The results of experiments with this tube are shown in Table III.

TABLE III.

	No. 1 at 30° E.	No. 2 at 90° W.	Ratio $\frac{No. 2}{No. 1}$	No. 1 x Ratio	Per. cent. change in intensity	Reading of voltmeter
Lead...........	66.3	81.8	1.113	73.8	9.8	22.0
	72.0	88.1	1.113	80.2	8.9	22.5
	72.2	88.6	1.113	80.3	9.4	22.0
Silver...........	69.1	85.4	1.113	76.7	10.0	22.5
	69.9	88.1	1.113	77.6	11.7	22.0
	67.2	84.2	1.113	74.6	11.2	21.5
	68.0	85.3	1.113	75.7	11.3	21.5
Lead...........	72.3	91.8	1.106	79.9	12.9	20.8
	73.8	95.6	1.121	82.7	13.5	20.0
	72.5	93.2	1.121	81.3	12.8	20.0
	72.1	92.3	1.121	80.8	12.5	20.6
	75.5	92.6	1.100	83.0	10.3	20.5
	74.8	92.6	1.100	82.3	11.6	20.6
Silver...........	75.7	94.8	1.100	83.3	12.1	20.0
	70.0	87.1	1.100	84.7	11.6	20.5
	72.9	90.9	1.100	80.2	11.7	20.8
	66.3	84.6	1.100	73.9	12.8	20.8
	72.3	91.8	1.100	79.9	12.9	20.8
	75.7	93.8	1.100	83.3	11.2	20.0
Lead...........	63.5	83.5	1.113	70.7	15.3	21.5*
	64.2	84.2	1.113	71.4	15.2	22.0
	57.3	76.8	1.113	63.6	17.0	21.0
	67.0	86.9	1.113	74.6	14.2	22.0
	66.7	85.3	1.113	74.0	13.2	22.0
	63.7	82.3	1.113	70.8	13.9	22.0
Silver...........	64.2	83.7	1.113	71.4	14.7	22.0
	65.8	85.0	1.113	73.2	13.9	22.0
Lead...........	23.7	32.2	1.115	26.3	18.0	16.5
	60.2	79.1	1.115	66.2	16.7	16.8
	59.7	80.3	1.115	66.6	17.0	16.0
	54.7	75.6	1.115	61.0	19.3	16.2
	60.5	80.4	1.115	67.4	16.1	16.5
Silver...........	61.2	83.8	1.115	68.3	18.5	15.0
	65.1	83.8	1.115	72.6	13.4	20.0
	68.2	86.4	1.115	75.7	12.3	22.5
	59.0	79.5	1.115	65.5	17.6	16.5
	62.7	84.1	1.115	69.6	17.9	17.9
	68.2	90.9	1.115	75.7	16.5	16.2

* The distance between the condenser plates was made less; hence the following readings of the voltmeter indicate a lower potential than the above.

It appears that within experimental error no difference exists in the polarization of Röntgen rays from a lead target and a silver target.

In conclusion I wish to thank Dr. Ham for suggestions and advice throughout the work and Mr. W. P. Davey for assistance in arranging apparatus and taking readings.

Manganese Steel. ANON. (*Eng. Record,* lxiii, 63.)—Wrought manganese steel is now carried in stock in the form of rounds, flats, plates, sheet bars, billets and blooms. The rolling and forging of manganese steel was declared to be impossible for some years after the Taylor Iron and Steel Co., had established manganese steel castings on the market. Nevertheless the Manganese Steel Rail Co., has developed a process of rolling and forging. It will be observed by those who look into the details of the conquest of manganese that the real work has been done by men of distinction as students and savants, like Prof. Howe and Dr. Cushman, rather than by mill-men, whose experience makes them question the practicability of methods not founded on the physical facts familiar to them.

The Absorption of Nitrogen by Aluminum. ANON. (*Brass World,* vii, 1.)—Aluminum has several properties diametrically different from other metals, and one is its power of absorbing nitrogen from the air. This absorption is believed to be responsible for blow-holes and a reduction in tensile strength. This absorption is clearly shown by wetting a mass of aluminum skimmings, which will, in a short time, smell strongly of ammonia. In melting aluminum it is not customary to cover it, *e.g.* with charcoal; hence the molten aluminum has ample opportunity to absorb nitrogen. Hitherto oxidation has been considered the cause of injury to this metal when overheated, but undoubtedly the absorption of nitrogen is another factor.

Pendular Hardness Gauge. DR. ING. J. KIRNER. (*Amer. Mach.,* xxxiii, 972.)—This hardness testing machine is constructed in the form of a pendulum. The hammer carrying the striking truncated cone is swung by a rod from a post provided with levelling and other adjustments. The bar of steel to be tested is held in a vise presenting its end to the hammer. The hammer is raised so many degrees measured on an arc scale, and the extent of the rebound is measured. The end of the bar requires little preparation and the hardness is determined over the whole cross-section. It is said to be accurate for practical purposes.

Effect of Cold on Plating Solutions. ANON. (*Brass World,* vii, 2.)—In cold weather there is difficulty in obtaining a good deposit as rapidly as in summer, owing to the low temperature of the plating solutions, which will not work well when down to 30° F. or 40° F. The best results are obtained by maintaining the solutions at a uniform temperature all the year round or about 70° F., which can be easily done by a steam-coil. Cyanide copper and brass solutions are more affected by cold than silver or acid copper solutions. Nickel solutions are considerably affected, though not so much as cyanide copper or brass solutions.

NATURAL AND ARTIFICIAL DRAFT.*

BY

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My subject to-night falls naturally into two parts, in the first of which we will consider the properties of Natural Draft, and my remarks on this will repeat in part a similar presentation of the same subject which I have given elsewhere.

NATURAL DRAFT.

We see in nature the fire burning on the open ground, making its own natural draft produced by the current set up by the ascending heated gas of lighter density rising therefrom. If the wind blows against the fire it is greatly kindled and the heat becomes intensified, but when the air is quiet again, the combustion becomes more sluggish. Hence primitive man no doubt imitated the wind with his lungs or by fanning. The discovery of confining the heat up a vertical tube to make a better combustion we can also suppose to be within the limits of this period, although the uses made of these applications were not based upon any scientific study or knowledge of the causes producing these effects in the way we are endeavoring to understand and apply such principles more intelligently in our discussion here this evening.

The term " natural draft " as in general use at the present time we understand to refer to the draft produced by the tube or chimney unaided by any other means and for a while we will confine ourselves to this restriction of our subject. The importance of a good draft is becoming more appreciated as the demands for greater steaming and the closest economy in generating, are found to depend ultimately upon the ability of the chimney.

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* Presented at the Meeting of the Mechanical and Engineering Section, held Thursday, February 23, 1911.

Nearly every treatise pertaining to chimneys and natural draft will be preambled with the following statement: " The natural draft obtainable from a chimney depends upon the column of gas inside the chimney being lighter than the air outside." This, however, is not altogether the sole cause in producing draft, as a wind blowing over the chimney produces considerable suction without the inside air or gas being heated at all; in fact, I have tested chimneys where I have obtained a slightly higher draft pressure than the temperatures and height figured to be possible. As there is always some wind in nature, this supplemental aid to the scientific quantity of draft that we have produced by heat, is of importance and of considerable value, many localities thus favored obtaining a draft equivalent to perhaps 25 or 50 ft. more of chimney height; nevertheless, as the wind is such an uncertain element we have to fall back in foresighting our calculations to what may be reliably obtained from an assumption of height and temperature conditions for producing a given draft by the stack.

There are only two dimensions to be determined, the height and the area, and we will consider first the matter of selecting the chimney height. A proper height is of the greatest importance as this produces the dependable pulling force. This force must be sufficient to overcome friction through the grates, and this quantity varies according to design and percentage of air opening.

Through the coal, which depends upon its depth, quality, tendency to clinker and the intelligence of the firemen.

Through the boiler, which is more or less according to its general type and bafflings.

Through the flues and chimney, which is affected by their size and shape as whether square or round and the crooks and turns and whether of brick or iron, the former making for more resistance.

Consideration for the adequate draft to cover these factors is no simple matter, but nevertheless should be squarely met.

The providing a good height of stack to produce a strong, vigorous draft involves some expense, but this expense can be offset by the use of fewer boilers at a less cost for a smaller building, as well as in the saving for foundations and piping.

It is becoming generally appreciated that there is also a con-

siderable economy in running with fewer boilers, due more or less to the following causes :

First.—There is less expense for banking same at night, as it costs no more to bank at night a highly developed boiler than for one running under or at normal rating.

Second.—With an intensity of fire the gases are more completely burned to CO_2. A low flue temperature does not indicate that the gases were completely burned, and in fact it generally shows that they were not, as well as having an excess of air.

Third.—The better circulation set up and this more rapid circulation of steam making for better boiler efficiency. I remember in my reading of an interesting account of a discussion on this matter. I think it was before the New York Railroad Club by some English engineers, going into the matter of heat transferrence from the fire to water in passing through iron plate or boiler tube, in which they maintained that experiments had absolutely proved that there was a better transferrence of heat to ebullating water than to still water, and abroad they have carried this out logically in firing special boilers to heat the water for the steam making boilers to enter as near their steam making point as possible.

Fourth.—Although aside from any use of the Economizer there is generally a greater gain to be had from an intensive furnace, it is apparent that the economizer value is increased greatly in bringing to a conclusion the all around efficiency to be had from intensive firing by reducing the heat in the flue down to the lowest point allowable to sustain draft, thereby making for practically as perfect utilization of the heat that is to be had.

Fifth.—Less smoke produced. A good draft is necessary to the successful operation of any stoker, hence given the same co-operation to ordinary grates, less smoke will also result if combined with some intelligence that the firemen does not blanket the whole of his fire with green coal at a single operation.

Should some one rise to prove the opposite, I would be prepared to say that where experience has been found against attempting such heavy coaling and overrating (forcing, if you please) and where better economy was found to be had by running more, rather than fewer boilers, that such cases will usually be found where a poor draft exists, requiring more boilers to be used to get a larger grate area to spread the coal on thinner.

Speaking of forcing, the use of any chimney is to force the fire. So every fire not left to smoulder or burn on the open ground is a forced fire. If you considered your boiler merely as a large kettle of some unknown size, whatever you could get out of it would be the capacity it was good for. Suppose you could get twice as much performance, or more than before, from any kettle, you would not consider you had caused any strain or injury nor would you; hence the word " forcing " in the sense of working beyond or close to its safe usage as would be in mind by the use of the word applied similarly to an engine does not exist. So long as the limit of safe pressure is never exceeded, the safe output of steam is unlimited.

It has come about in practice that the purchaser wishing to produce 1000 boiler h.p. that the builders generally furnish him 10,000 sq. ft. of heating surface or 10 sq. ft. per horsepower, as it is a safe measurement to use with a very ordinary draft. But whether the purchaser obtains 1000 h.p. or twice that, out of the size he has bought, is purely a matter of supplying heat enough and that is practically limited only by the draft strength to burn the requisite coal on the grates. As stated before, conditions may make it otherwise, as with a definite chimney draft installed, the efficiency may be better below the builder's rating, at rating, or above rating.

So where a person is planning a new chimney, his course for determining the size should include consideration of the following:

For the Height.—1. The local advantages of the situation, as to exposure to wind and its general climatic dependence. As a general statement a high elevation at start for the foundation is an advantage, still it is not necessarily so, as sometimes a valley situation may be so placed that it may have an unusually strong current of wind drawn through same and seldom troubled with cross winds which would cut off the sweep above the chimney, but ordinarily the valley location demands a higher chimney to protect the plant against the loss of draft it would have, were it not hemmed in.

2. The placement distance of the furthest boiler or boilers, relative to the stack.

3. Type of boilers and grates.

4. Quality and depth of coal.

It is universally taught that " draft " varies as the square

root of the height, but this use of the word " draft " applies only
to the capacity which is more a matter of area, as I will show
later.   The prime thing is a proper height, as it is this factor—
adequately ascertained—that gives you the assurance of a provis-
ion for the essential force or pull to run your plant at a reduced
expense for boilers, for their setting, piping and size of house.
and with a better economy to boot.   I wish you to note the
distinction between draft pressure and draft capacity; the word
" draft " is used too indiscriminately to either function and is
unscientific as well as confusing.

Chimneys give a draft pressure in direct proportion to their
height, thus 200 feet gives twice the pressure of 100 feet and the
pressure is the same for all chimneys having the same height
whether the area varies between them as 1 or 50 sq. ft. in section;
hence, if I have figured it for you on a reasonable assumption of
450° in your flue gases and tell you it is 0.6 of an inch with a
stack 100 ft. high when the outside air is 60°, then you will know
that to obtain 0.9 of an inch that 150 feet height would be
required regardless of any area, and for 1.2 inches the height must
be 200 feet and so on.   Afterwards selecting the area to suit the
volume from the expected amount of output.

This factor 0.6 of an inch per 100 ft. of height the writer
believes is a safe basis, as in the winter time the outside air is
colder, making for a still better result, and while in the summer it
would be somewhat less by the outside air being hotter than the
assumed 60°, yet the heating system is off so that the work will
be usually somewhat less, and in addition you have two likely
forces that will most always make the draft better than this
given factor, namely, the assistance of the wind and more fre-
quently hotter leaving gases.

Many papers have been written on the subjects of chimneys
and drafts, generally developing abstruse or speculative theories.
The most helpful and practical that I have come across was in a
recent article by T. F. J. Maguire. which gave definite measures
of draft resistances.   (See Table I.)

Loss of draft in boiler setting he measures as 0.3 of an inch
to Water Tube boilers, increasing to 0.4 of an inch with 50 per
cent. overload.   Of course he intends this to be used with some
judgment in application to the special boiler in mind. as to its
construction and bafflings.   The writer believes Horizontal Re-
turn Tubular boilers will be found to require the same allowance

and the Manning and Vertical types half of this or 0.15 of an inch. You do not have to take any multiple of the factor by the number of boilers.

Loss of draft in breechings. Maguire allows 0.1 of an inch per 100 ft. of length to circular iron flues and 0.05 of an inch for each right angle turn. If squares or rectangular shape, increase the above 25 per cent. For brick flues increase the above 30 per cent. The writer would allow for the stack travel the same as for the breechings.

The supplying of these reliable factors for fixing chimney dimensions on an intelligent basis to meet the duty that will be required is of great service.

Let us see how the application of such factors would apply to a concrete case where we assumed we wished to burn 25 lbs.

TABLE I.—DRAFT PRESSURE REQUIRED IN FURNACE.

Kind of coal.	Pounds of dry coal burned per square foot of grate per hour						
	15	20	25	30	35	40	45
	Draft in inches of water						
Eastern bituminous coals............	.12	.16	.20	.27	.34	.42	.52
Western bituminous coals...........	.15	.20	.25	.33	.42	.52	.65
Semi-bituminous coals..............	.15	.20	.28	.37	.48	.60	.80
Anthracite buckwheat, No. 1 and larger..........................	.45	.70	1.00				
Anthracite buckwheat, No. 2 and No. 3............................	.75	1.30					

of soft coal under Horizontal Tubular boilers with two right angle turns in the breeching.

Furnace draft for 25 pounds soft coal.................... 0.2
[1] H. R. T. boiler 0.3
50 feet of steel breeching 0.05
Rectangular shape 25 per cent. additional............... 0.0125
Two right angles 0.1
Round brick chimney 150 feet........................... 0.15
Brick surface 30 per cent. additional.................... 0.045
                                                         _____
    Total draft required 0.8575

[1] Resistance increases with velocity, if therefore 25 pounds per square foot would develop a considerable amount above rating, add a third to the boiler resistance. In the above it would therefore be 0.4 for the H. R. T. instead of 0.3 for its normal. This addition of increase will probably cover the flue resistance as well.

Or approximately 0.9 of an inch, and as we can get 0.6 of an inch of pressure per 100 feet of height, then a 150 ft. stack should provide the total pressure needed. Notice that this stack height is indifferent to any size or amount of horsepower output, except as more boilers would require allowance for longer flue travel which would be very slight.

I would like the opinion of others on this showing, because if general practice is shown to coincide, it will be of much value and equally so if more reliable quantities can be established. I know at the outset that some will claim to have a 150 ft. chimney and cannot burn at this rate, and if so, the cause may be found due to excessive area absorbing the heat needed to produce the expected draft pressure or to some other accountable reason.

It may be pointed out that no allowance for economizer draft effect has been listed. But as the straight open-passage type of economizer has generally a greater free area than the flue, it can be reckoned on its length as for flue distance. Further, you must know that the top layers on the coal bed make for a greater proportional resistance, so an economizer saving 10 per cent. of coal, would ease the fuel resistance to produce the same output of steam, thus practically offsetting any effect of its own resistance, while the owner is 10 per cent. of coal in pocket with a proportionate draft pressure needed to accomplish the same output. This has proved universally true through a period of over half a century, so that the exceptions are now known to be due either to its faulty installation or fault in the design and size of the economizer selected.

Until further tests have been made to determine the actual pressures required for the usual run of commercial qualities of coal depths on grates, these figures may be treated with some caution, yet faulty as they may be, they will prove in the main quite trustworthy as a deviation will probably be found to be offset by some other, so if the boiler makes more friction, the coal perhaps will prove less. Hence, I believe determining your chimney height on a basis of such quantities, better than making a vague guess as it is generally being done now, and no one will welcome corrections to the foregoing calculations more agreeably than myself, knowing a true schedule would be of the greatest value to every power producer.

You observe the size of plant and number of boilers, except

as they effect the flue distance, have no consideration in this matter of height determination. That there is no definite height to correspond with a given size of horsepower will be seen if a stack of sufficient height to suit a 1000 h.p. plant is arranged as in Fig. 1.

Fig. 1.
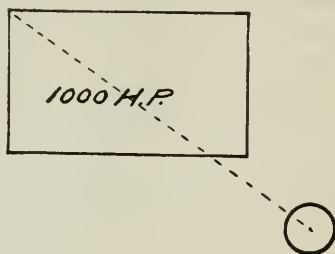
That the same height should be equally sufficient with a proportional increased area for 2000 h.p. arranged as in Fig. 2.

As the length of pull to the furthest boilers is no greater a demand than that for the single 1000 h.p., so too, the same height would be satisfactory to 4000 h.p. of boilers arranged as in Fig. 3.

Fig. 2
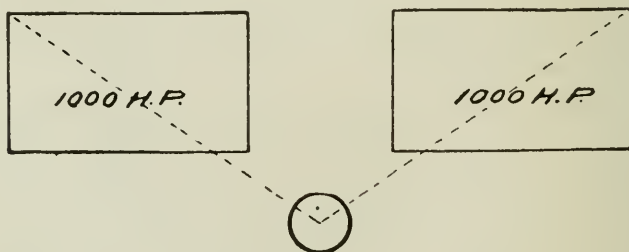
As the gases travel about 70 feet a second, a distance of 20 feet more or less is negligible in the flue resistance as is the fact of using an Economizer, presuming the Open Tube style is used with a free area equivalent or greater to the flue giving a straightway passage. The prime requisites therefore for determining the proper draft pressure are the coal depth and the boiler type.

For the Area.—The size of the plant determines the area. The boiler horsepower of the output should not be considered in determining the height as we have just seen and as is mistakenly being done now, with rare exception, but it is the sole basis for determining area.

The selection of a suitable area to a chimney is as frequently a guesswork dimension as for selecting the height. Some have a pet rule of making it proportionate to the grate surface, regardless of the fact that if twice as much coal is burned in one case as in the other, it would call for twice the flue area, because having

Fig. 3.
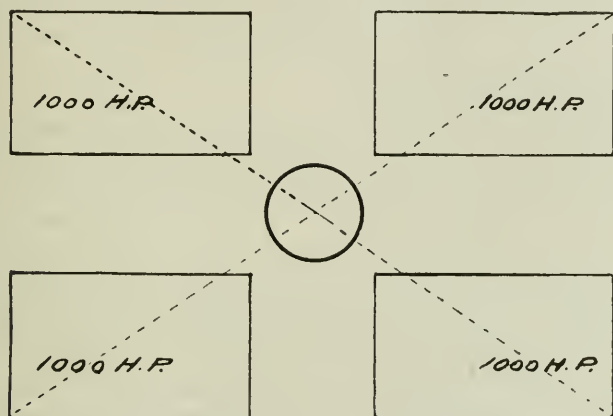
double the amount of gas volume of the other. Others figure up all the tube area in their Horizontal Return Tubulars or Mannings or measure up the outlets of the water tube, etc.

As to build to good height costs so much more in proportion than for area, it is a common fallacy to curtail on the former and increase the latter. Thus for 1500 h.p. the owner provides himself with a stack of a height suitable for only 1000 h.p. and uses an area good for two or three times this amount and wonders why, after putting up a stack " said to be good for perhaps 3000 h.p." he has difficulty in getting 1500 h.p. and has to have recourse to artificial aid. The theoretical area required for 1000 h.p. of boilers with a stack only 100 feet high is but 7 square feet under ordinary conditions. In my own practice, I usually allow

20 sq. ft. for a single 1000 h.p. boiler installation as being ample for this amount of horsepower at normal running and also as allowing for the reasonable increased growth of plant and overload. For two or more thousand horsepower I reduce this area allowance about 10 per cent., increasing the reduction on very large plants to perhaps 20 per cent., keeping 16 sq. ft. as well within a safe limit per 1000 h.p. where the plant becomes several thousand. For smaller plants, say, 500 h.p., for instance, I would allow 12 sq. ft. which is then more than three times the theoretical area on the moderate basis of a height of 100 feet.

If the chimney is above 100 feet in height, the theoretical 7 sq. ft., requirement is still less, and as I say, I never take less than 16 sq. ft. of area, which is more than double the theoretical for 100 ft. high. I consider that it is ample allowance for any overload, as well as safe, and I have never found any difficulty in practice by its application.

The smallest allowable area should give the best draft, as were we to increase 20 sq. ft. per 1000 h.p. to 30 sq. ft., it would mean in a travel of 150 ft. distance up the stack, assuming this height, together with a flue length of 30 ft. to reach its port, that we have added 645 sq. ft. of surface to be warmed to the same temperature of the gases with exposure to radiation loss, as well as increasing the air leaks caused by the chimney suction through flue seams and the porous bricks of this added surface. All of this excess surface put on by unneeded area is therefore making for a great detriment to the pulling force of the stack so essential for keeping down the plant investment as well as for its economy.

On the same basis of conditions as for the 100 ft. stack to be used for determining the draft pressure, we find that 69 cubic feet will be passed per second per each square foot of area.

Assuming then our boiler horsepower requires as much as 4 pounds of coal per horsepower and while theoretically 12 pounds of air is needed to burn a pound of coal we will use 20 or plus the pound of coal involved,—21 pounds of gas or 84 pounds gas per boiler horsepower. So as calculation shows, we have therefore for 1000 boiler horsepower with a short stack of only 100 feet high, the startlingly small area of 7 sq. ft. actually needed. If the surface friction needs to be set off, surely 25 to 50 per cent. is ample allowance, and then as you think the plant may run above rating, or increase in the future, use your judgment as to

further percentage of increase to same; but do bear in mind that excess area beyond reasonable future requirements does not assist at all in pulling the needed air through the coal heaped on the grates.

Surely 4 pounds of coal per horsepower and 21 pounds of gas per pound of fuel are reasonably large factors, so if requiring actually only 7 sq. ft. per 1000 h.p., why such tremendous excess areas are invariably allowed, is a puzzle. I suppose it is done because it is cheaper to provide more area than the needed height and therefore we see something like a 2000 h.p. or more area with an inferior height provided to be used for only 1000 h.p. and proving in such cases that where the short stack height is a fault to begin with, it is made worse by hitching it together with an undue area. In actual practice the writer has found several stacks work close to their theoretical area capacity, as for instance at Lawrence, Mass., a chimney 128 feet high above grates with flue area of 9 sq. ft. took care of 6 Manning boilers in a satisfactory manner, developing 780 h.p. whereas the usual chimney tables recommend this size for approximately only 300 h.p.

The movement of air follows the law of gravity, $V = \sqrt{2\,gh}$. So the difference in capacity between stacks respectively 100 and 200 feet high would, therefore, be in proportion to their square roots, as 10 is to 14, which is small for such a great difference, so I ignore it altogether and taking an area that I know to be right to the smaller, which is 7 square feet theoretically and increasing this to 20 square feet for use in practice per 1000 h.p., for any height of chimney, I know it must be even more safe if there is a greater height than 100 feet. So I believe this is the largest area for best results and using any greater factor than 20 sq. ft. can only be detrimental to the draft force.

While I do not wish to deter those who have time and the disposition to figure a given chimney problem with accuracy, yet I believe the factors, 0.6 of an inch pressure per 100 feet of height and the area factor at 20 sq. ft. per 1000 h.p. for all heights, will be welcomed by many as safe quantities to work to in selecting the two required dimensions of a new chimney.

If you must add something for "good luck" put it on the height, as you stand to lose less on this, as the excess area will only come useful in a long distant future when the plant has

grown to it, as the 20 sq. ft. basis for area is nearly three times
the theoretical and it provides sufficiently for all needs of reason-
able increase.

I have seen too many plants handicapped by strained propor-
tions for a great future, whereas when the future did arrive, it
was entirely a different mill or a problem altogether dissimilar to
any initial conception. In following the mill development for
twenty years in New England, it has inclined me to believe that
if I had the making of any new power plant layout, it would
be my purpose to plan for the highest economy for the immediate
needs, not extending farther perhaps than the next five years.
This burdening a new plant to struggle under heavy fixed charges
and loss in operating until the work develops to meet the initial
undue proportion, is as bad as buying a man's suit for a boy
because you know he is going to grow to it some day. Make
things of right proportions to get the best economy for what you
need now, and when success brings ample capital you can then
easier afford to throw away the old plant, if you like, and start
out with another up-to-date outfit. In our conceit at any present
time, we lay out big schemes for additional future boilers of the
same kind in a great shed of a building and what is found gener-
ally ten or fifteen years later, is a collection of big and little units,
different makes, different piping systems, etc., with the same
thing seen in the engine room and elsewhere.

Realizing the convenience of using the chimney tables in
vogue, I hope my two factors of 0.6 of an inch per 100 ft. of
height and 20 sq. ft. area per 1000 boiler horsepower will prove
a simpler and better substitute, and when used with intelligent
study and tabulation for the needed height for pressure, will make
your future chimneys a better investment.

In regard to the character of the chimney construction in gen-
eral use, the most efficient and handsomest, in the writer's opin-
ion, is a well designed red brick or radial brick chimney with
an inside core. The next selection would be such brick chimney
without a core, following which would be a lined steel stack, with
the unlined steel pipe the lowest in order. There is another
advantage besides the better retention of heat, in having a core,
as it can be taken out if more area is ever needed and in many
cases this has been done.

Concrete chimneys are being built also, but some good en-

gineers are afraid of them as they claim that concrete is such a brittle substance that owing to wind vibration it will certainly in time open fissures through the thin shell, which will permit the entrance of moisture and combining with the sulphur gas destroy the reinforcing iron bonding the material.

To make my paper practical to those of my hearers who have chimneys already built, I would say that yours is a case of studying your conditions to see what you can best get from them and suggest that you try running your plant on as few boilers as possible. I believe the result will prove decidedly advantageous. You must have the engineer interested to give it a fair trial as it may mean a little better attention to fires to prove it out, because if you are troubled with weak natural draft you must break up the fires oftener and study closely to obtain more intelligent and more intensified firing.

In winter, if you are troubled with poorer draft than in summer, it is due to having the boiler room too tightly closed. If the firemen object to cold drafts from doors and windows, provide the air entrance from the top of the room.

Often the wind in certain directions, instead of assisting the draft makes for the contrary, which condition occurs when the wind is blowing in the direction towards the further boiler house door and this being kept open, the suction of air follows along in the same direction out through same, so that the end boilers nearest to the door have difficulty in getting their supply of air through the grates.

An unutilized excess of draft pressure is bad and the boilers should be fired as near the limit of draft as possible so as to prevent such excess, but there will at times be necessarily a considerable surplus pull by the wind producing a greater draft one time than another. That this excess draft is more common than otherwise is shown by the operation of the automatic regulation of dampers in the general run of plants, continually cutting off 25 to 50 per cent. and more of the available draft throughout the entire day. Of course as the plant is being run, the damper regulation makes for a great saving in preventing an undue excess of air through the grates, but the force should be put to work so far as possible to produce a more intense fire and by heavier coaling to run with fewer boilers.

In this matter of draft regulation, it is much better to have a

regulator that operates slowly than to have one so sensitive as to be opening and closing on a slight variation of pressure, thereby letting in an excess of air one minute, and then tightly closing, cutting off the air supply altogether which makes for another loss to follow by imperfect combustion.

If you have such a sensitive damper, it is not necessary to throw it out, just limit your range of damper opening, so that it does not shut tight or open to its fullest extent. The regulating damper should be as near the chimney as possible, and if it were placed at the top of the chimney, it would be better yet, as in times of closing, it would hold back that much more heat. As it operates now in many plants, when the damper is closed at the port, the brick lining or core begins to lose immediately its stored up heat and the chimney cools off, then when the demand for steam comes instead of an active chimney agent, it takes a bit of a while for it to recover its lost heat and give vigorous draft; meanwhile, the plant is held back in getting the supply of steam demanded. The condition becomes worse where the regulation is applied to dampers in the boiler uptakes, as during the time of cut off the flues have cooled as well as the chimney.

It will not be denied that any sort of a chimney gives some draft, in fact, a fair draft as practice is to-day, but I maintain that the average draft is not up to what it might be and should be, hence we are generally using too many boilers and firing at a disadvantage for the best economy. New boilers are purchased to get thinner fires or artificial draft frequently installed that would be unnecessary if the chimney were properly worked out in the beginning.

THEORETICAL CAPACITY AND PRESSURE TO A CHIMNEY 100 FEET HIGH.

1. Assumed height   = 100 feet.
   Assumed area   = 1 square foot.
   Assumed gases   = 450 degrees Fahrenheit.
   Assumed outside air = 60 degrees Fahrenheit.

2. The first step is to ascertain how high the 100 foot column of air will balance a column of gas at 450 degrees Fahrenheit.

The density of a gas varies in direct proportion to its temperature from absolute zero ($461°$ below $0°$ Fahrenheit).

$$60 + 461 : 450 + 461 :: 100 : x,$$
$$\text{or} \quad 521 : 911 :: 100 : 175$$

3. Velocity or fall will be the difference between 100 feet and 175 feet or 75 feet.

And velocity is expressed by the familiar formula

$$V = \sqrt{2gh}$$

Calling g, which is the acceleration due to gravity 32, this formula becomes

$$V = \sqrt{64h} = 8\sqrt{h} = 8\sqrt{75} = 8 \times 8.66 = 69.28.$$

That is, for each square foot of area there will be 69.28 cubic feet emptied per second.

4. The weight of chimney gases at 450 degrees has been determined to be 0.045 pounds per cubic foot, hence:

$$69.28 \times .045 = 3.1176 \text{ pounds per second.}$$

3.1176×3600 seconds per hour $= 11,223$ pounds gas per hour per one square foot of area.

We now have a practical, safe result to work with.

If we assume 84 pounds of gas per 1 boiler h.p. then $11,223 \div 84 = 133.6$ h.p. per square foot of chimney area.

1000 h.p. of boilers with stack only 100 feet high requires theoretically therefore only 7 square feet of area and if above 100 feet high, it would be of course less.

Now you can double this area in practice or triple it, but when some quadruple and quintuple this amount, it is time to halt as the increase adds nothing to the effectiveness but the reverse.

As to pressure:

A cubic foot of water weighs 62.37 pounds and one inch of this equals 5.2 pounds, so if we divide the pressure per square foot by this or multiply it by $\frac{1}{5.2} = 0.192$, we shall have the height of column of water which it will support in inches.

The weight per cubic foot of a gas at any temperature may be found, therefore, by dividing this constant product of the weight and absolute temperature by the given absolute temperature.

Air at 32° weighs 0.080728 pounds per cubic foot. Its absolute temperature is 493.2. The product of this weight and temperature is

$$0.080728 \times 493.2 = 39.8$$

So that to find the weight per cubic foot of air at any temperature it is necessary only to divide 39.8 by that temperature plus 461.2, *i.e.*, by the given absolute temperature and we can say, calling the density or weight per cubic foot D,

$$D = \frac{39.8}{t + 461.3} \text{ or } D = \frac{39.8}{T}.$$

The weight of a cubic foot of chimney gas, which is not simply heated air, but a mixture of nitrogen, carbonic acid gas, etc., would be about 0.084 of a

pound per cubic foot at 32° for perfect combustion of ordinary coal, and 24 pounds of air to the pound of fuel. Its weight per cubic foot or density at any other temperature would be

$$d = \frac{.084 \times 493.2}{t + 461.2} = \frac{41.43}{T}.$$

Density of air at 60 degrees $= D = 0.0763$
Density of gas at 450 degrees $= d = 0.0454$

.192 x 100 feet stack x (0.0763–0.0454) $= 0.593$ inches, practically 0.6 of an inch, and will be the same for all stacks 100 feet high when the gas and air temperatures are the same as the above, regardless of any difference in area or whether only one square foot or fifty.

ARTIFICIAL DRAFT.

So many favorable comments and demands were made for copies of my previous paper on natural draft which showed the wide-spread interest of intelligent students to secure tangible and more definite knowledge of that subject, that I am glad to have opportunity here to add some remarks and suggestions to the use of Artificial Draft as it is a subject of rapidly growing interest and importance, as natural draft is so varying in its action between different places—and in the same place—and in one hour with another, that no exact rules can be made in regard to it. Hence the broad empirical formulas for chimney sizes and the wide divergence in practice of heights and areas that are seen in use to handle similar amounts of boiler horsepower—being based on opinions and deductions more or less sound from the experience of their engineering advisers.

Utilization of forces in nature which are affected largely by the weather have an uncertainty of reliability—such as tidal power, wind-mills, water-falls, etc. When, therefore, the use of such a fluctuating force is made the sole reliance for the economical burning of fuel and with public service corporations to meet unfailingly the growing demands of their patrons—the engineering talent is found perplexedly attempting to formulate definite rules or regulations to constantly changing firing conditions, which at best can only be general, or practically to make the best use of whatever draft is available at the time, so what measure of success is attained thereby is, of course, to their credit.

The never-failing interest on the subject of natural draft and

the more general realization of its elusive quality to be confined within any certain formula. is making for greater study of the advantages of artificial draft for producing a definite positive draft pressure for the right volume that will be suited at all times to precise needs. Combustion being a chemical action which is an exact science, it is possible to make definite experiments of the requirements of any fuel for its complete combustion and then maintain the same in constant everyday practice very closely if given the operating facilities that will reliably supply the conditions determined by the laboratory and experimental investigations.

The generalities of this subject have been well stated by Mr. C. E. Roehl in a discussion before the American Street and Interurban Railway Engineering Association where he said:

" Capacity is fundamentally a matter of rate of firing. Firing rates vary widely, whereas efficiencies with a given grade of fuel do not; therefore, it follows that it is only necessary to get coal into a furnace and burn it to cause the rate of steaming to vary very nearly in proportion to the rate of firing. The practical response of the rate of steaming to the rate of firing follows logically from the modern recognition that with boiler equipment actually in service at the present day, the limitation of the heat transmitting ability of the metal of the heating surface is not approached.

" Higher steaming capacity usually reduces labor charges and inevitably reduces investment charges. It reduces the labor charges because, as a rule, more coal per man is being fired and more steam per pound of coal is being obtained. Investment charges are reduced because greater power is obtained per boiler. Maintenance charges increase, but the increase is practically confined to the furnace and, except in very special cases, while an offsetting factor, it is not a ruling one.

" Moderate increase of evaporating rate, 100 or 150 per cent., or perhaps more. must be brought about. Installation of very large capacity city turbines has forced this and in isolated instances a good deal has already been accomplished. There seems little reason to doubt that the best which has at present been accomplished will in a few years become standard practice."

Another statement on this subject from the *Electrical Engineer,* London, is worth attention:

" It is frequently quoted that with mechanical draft a smaller excess supply of air than that demanded by theory is required than with natural draft. In all probability this arises from the fact that natural draft pressures, are, as a rule, considerably lower than those mechanically produced, and fires are worked with less thickness with the former, so that such a thorough and uniform mixing of the coal and coal and air does not take place as with the great pressure and thicker fires of the latter."

Artificial draft may be either of two systems or a combination of both, namely, the Induced Draft, Forced Draft or Balanced Draft.

The Induced Draft or Suction Draft has all the advantages of the natural chimney draft, with the additional assurance of providing almost any positive required draft pressure that will be needed and where the plant is in its infancy, it is frequently better to use an inexpensive induced draft than to incur the investment charge for a huge chimney against future needs which are indefinite, perhaps to a remote period. While generally the cost of the induced draft is 75 to 80 per cent. less than an equivalent chimney capacity, its proportionate expense is not fixed, as the greater the chimney height, the less the induced draft equipments cost in proportion and if foundations are particularly expensive for the chimney the relative difference in cost becomes greater in favor of the induced. By using powerful fans the outlay for boiler installations can be reduced at least 25 per cent., and in one case the company I represent cut it by one-half with great success. This saving would fully offset the expense for the highest standard of mechanical draft equipment—or put another way, chimney cost would be saved altogether.

The maintenance of the induced draft is very small. If the plant is large enough to warrant using Corliss type engines, the operating expense can be maintained at less than one per cent. of the steam produced. In ordinary moderate sized plants the expense for operating a well designed equipment would never be more than double this, or 2 per cent., which would be an extreme to produce an extraordinary pressure. The equipment stands up well with small risk of break-down and by attaching a pulley which can be operated by a belt from the main drive or to an electric motor, the plant is insured against shut-down without the expense for duplicate apparatus.

Mr. Wm. R. Roney, in his valuable paper before the American Society of Mechanical Engineers, stated that the operating costs on several induced draft plants installed by his firm averaged about one-half of one per cent. of the horsepower of the total steam output.   As his paper was written many years ago, I hardly believe he would claim that to-day, although it would be as easy to do it to-day by simply attempting to equal the ordinary natural draft applied to plenty of boilers with ample grate area, but it would take nearly all of one per cent. of the horsepower output to meet the draft demand for the concentrated development embodied in the present larger boiler units, for to obtain double the draft pressure of former times requires three times the amount of power applied to the fan.   Calling it to-day then, one per cent. of the steam output, it is still a trifling cost commensurate with its results, while allowing all the exhaust from the fan engine to be utilized in heating feed water, the actual cost to produce the one per cent. of total horsepower output disappears almost altogether in fact, can well be ignored.

The writer has been much impressed with the growing demand for mechanical draft systems from manufacturers who may have only 200 horsepower or even less.   Formerly such parties would rush to their boiler maker for additional boilers and build costly foundations in an enlarged building, and then struggle to work in the necessary new flues and pipe connections— all at expense for money and time in delays.   Now, an inexpensive fan makes their present plant meet their growing increase and by further supplementing the boiler heating surface with Economizer tubes, the steam output may be even doubled with no excessive heat waste up stack—all accomplished rapidly at moderate cost and within the limits of the present building.   The boiler makers themselves are lending to the growth of artificial draft because owing to the competition among themselves, they know they can offer the purchaser a better trade per horsepower cost in the larger single units, which puts the buyer, however, to the expense of building a greatly higher chimney to obtain the expected rating or purchase the low-priced induced draft apparatus when he can then accomplish the rating with ease and even more.

Induced draft fans are usually provided with water-cooled bearings, to protect the babbitt from melting down, but I have

known where induced draft fans have been used for eighteen years without any such water, in fact, the bearings probably can be kept sufficiently cool by small openings in the fan case around the bearing so that some cold air will always be drawn over same. This had better not be attempted with direct connected engine sets, as it would draw more or less gritty dust over the engine as well, which would work into its bearings and crosshead. A half inch water pipe, however, will furnish all the water generally necessary to the largest size of induced draft fan. In my practice, I regularly install such cooling system as it is a very simple safeguard to adopt.

As a general rule, horizontal engines are preferred to very large fans if foundations can be had on the ground, but in elevated positions, the vertical type is preferred to avoid lateral vibrations.

The Forced Draft blows the air under the grates and the cost of operation is the same as for the induced draft, because, although it has a smaller fan, the weight of air to be moved in a given time is the same as the induced draft would have to handle if used at the other end.

There are different methods of regulating both forced and induced draft sets. Frequently an actuator is used to operate by means of crank levers, for regulating the fan speed by moving the governor. In my practice, I get precisely the same effect by simply inserting a pressure regulator in the steam supply to the engine.

Where forced draft is used in connection with a chimney draft which already is controlled at its port by an automatic damper regulator, another wire can be connected from it to operate a simple balanced valve in the steam supply to the forced draft so both the chimney damper and forced draft work in unison—such system is called *Balanced Draft*.

Whether Induced or Forced Draft is installed the engineer should study the operation of his fan engine and set his governor and cutoffs to suit the best uniform speed, because as the requirements are put up to the fan builders to meet the most maximum conditions contemplated, an ample sized engine with suitably adjusted cutoffs will be furnished to give ability to meet those extreme demands and too often the operator relies solely upon his regulator to take care of his load adjustment, with the result that the movement is constantly in motion, with the fan at one

moment working at its maximum and whooping the fires up so that the pressure gains for some time after the fan has slowed up. That the engineer should therefore make any new engine adjustment that may be needed to suit his normal conditions, should not require further argument. It would make for a marked improvement in economy and enable those in charge of the coaling to fire better under the more uniform draft conditions.

Speaking for New England, there are probably 10 Forced Draft fan systems installed to one of Induced Draft, indeed counting the various steam jet systems with same, I judge there are 50 forced fires to one artificial suction draft system. This is natural on account of the ease of installing the former, and its lower cost. Then, too, forced draft is better adapted for burning the fine grades of anthracite or buckwheat which pack on the grate so densely as to make too serious a demand for draft from any suction fan to be practical, whereas a strong underneath blast will keep the coal lifted and keep the particles in motion so the air is thoroughly mixed, producing a good fire with little smoke.

If the exhaust steam from the fan engine is blown into the air duct it will prevent clinker mass from forming and fusing on the grates. This has become quite a common practice and proves generally beneficial.

The forced draft usually makes a hot, dirty boiler room and frequently makes more arduous conditions of labor, as the heat tends to fly out upon them whenever doors are open. Then, too, the air blast seeks the weakest place of resistance in the fire and through such places produces holes letting in cold air to no good purpose. I think, however, there are considerable possibilities of economy with this system where firemen of superior intelligence are employed, as with carefully run fires, a thorough combustion can be obtained and the heat therefrom will be forced into effective contact with all parts of the heating surfaces.

The most common fallacy in regard to this use of forced draft is that it is a quick, inexpensive remedy where the present draft is inadequate. This proves true in some cases and in others, it will make for worse conditions than before.

The situations where it will benefit, speaking now as a draft remedy, will be where areas through flues and chimney are ample, although the height of the stack is too short to produce the necessary pulling force.

Whereas on the other hand, the case being one where the height and areas are both inadequate or outgrown, then the introduction of forced draft to such, requires a fierce blast to overcome the resistance ahead of the gases to reach the atmosphere and makes for such force against the boiler fronts as to become a source of danger to the men every time the doors are opened for coaling, also such a draft condition is injurious to the settings, as well as the fronts.

Forced draft, then, requires either a good draft at the other end, or paradoxically, no draft at all, but a short spacious path to out of doors. If any of you have forced draft in your plants which works too strenuously against the fronts and it is impossible to keep up steam with a lower air pressure, then you want to adopt the suggestions of providing easy vent after leaving boilers or improve chimney draft or adding the positive induced draft. But there is another remedy which might be worth trying if your boilers are of Water Tube Type, and that is, to remove the bafflings; your heat—as shown by the conditions of pressure around the front—is going to be just as efficiently brought in contact with the heating surfaces without assistance of the boiler bafflings in such cases.

Abroad intensive firing is being adopted on larger scales and in the development to achieve the highest results in some of the great electrical and industrial stations they are equipping their plants with huge thermal storage tanks in addition to their Economizers. These things are bound to follow in this country as progessive boiler builders realize that whatever helps the economical production of steam is to their advantage in keeping pace with their wide-awake competitors who are scientifically improving the efficiency of gas producers.

The prime movers of the plant have heretofore had the first place in attraction for study and development and thousands of dollars are spent to secure only a small economy which may be offset in the adjoining room by the firemen unnoticed. However, just as the public has had a surfeit of the moving signs on the Great White Way, so is coming the day when the owner will walk his visitor past the wonderful turbines into his boiler room and there throw out his chest with pride at its display of cleanliness, and its well-studied features to secure all the heat possible from the fuel by its most complete utilization.

MODERN COMMERCIAL FOOD MANUFACTURE.*

BY

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THE subject of food manufacture, whether it involves commercial or domestic food preparation, is at best, a homely and prosaic one—yet, withal, in itself, of interest, because of its large importance.

The relative importance to a nation of its food supply, in comparison with other essentials, is perhaps seldom adequately realized.

The food industry of the world is the world's greatest industry. From the tillers of the soil, and those who go down to the sea for its treasures, to the servitors at our tables, the number of those who are in some manner engaged in supplying the food demands of the human family, is greater probably than required for any other industry, as great possibly as for all others—vast almost beyond computation.

Food, shelter, raiment are the three great fundamental requirements of human life, and of these three food has been, from the beginning of time, the first consideration. To appease hunger was the problem of primitive man and his greatest stimulus to effort. His first and chief demand upon the earth and the elements about him was for food; and the first, last and most particular requirement of his civilized brother to-day still is that food be supplied him. This is the great common ground on which stand both savage and philosopher. Shelter and raiment were to aboriginal man of secondary importance—as they are also really of secondary importance to-day. Thus, being the one great essential to life itself, the struggle for food has probably been in all ages the influence that has contributed most to the survival of the fittest—the mainspring that has stimulated the action of the world.

It is not by any means an unwarranted assumption that the effort man has been compelled to put forth by this necessity has

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* Presented at the Meeting of the Section of Physics and Chemistry, held Thursday, February 16, 1911.

constituted the stimulus of human advancement—the responsible, underlying cause of our modern civilization.

For it is easily conceivable that if the incentive of hunger had not been given to the human race, the learning and luxury of modern times might have been much less evident, or that, if the daily demand of nature for food should miraculously cease, mankind would speedily retrograde.

If then, so much of our lives and so much of man's ambition are bound up in the great universal subject of " What to Eat and How to Get It," we surely do wisely to consider well what manner of food we are getting in return for life's struggle. Whether it is pure, clean and wholesome; whether it is calculated to give us the sustenance and strength, the health and prolongation of life that we have a right to expect; or whether it is sometimes so far a mixture of bad with the good, that almost literally we are given, when we ask for bread, a stone.

Food may be defined as consisting of those substances which are capable of sustaining the animal organism in a state of health and as that which makes possible the continuing existence of all forms of life.

There is a quality inherent in all food which, under natural conditions, renders it changeable and perishable. The atmosphere which surrounds us, coming as it does, in contact with every substance, unless removed or excluded as when in a vacuum, contains germs which are always active and whose mission is the destruction of all organic matter. These are the active causes of the change known as decomposition. To prevent such change, various means have had to be devised for keeping food from putrefaction and in a wholesome condition; drying, salting, chilling, heating, canning, coating with gelatin or fat for the exclusion of air, and the use of chemicals.

The practice of food preserving dates back to a prehistoric period. It is traditional, rather than historic, that man in the early ages, by a simple drying process, was afforded a means by which the accumulation of bountiful years and the surplusses of seasons of plenty could be carried over to provide sustenance through lean seasons and years of famine.

In hot climates, the heat of the sun was probably at first the sole preserving agent; while in colder latitudes where shelter and artificial heat were needed, we may well believe that the dis-

covery of the preservative quality of wood, smoke and the taste for smoked meats and fish closely followed the discovery of fire itself and came about through the suspension of the family larder from the roof of the family hut, where the food became impregnated with the rising vapors from burning wood and peat.

It is thought that the first discovery of the preservative use of salt was quite as accidental and due to the finding of meat carcasses in a good state of preservation, embedded in the incrustations of saline deserts.

Meat and fish, as well as fruits and vegetables, have also been kept for certain periods by sugar alone, but in the light of later day experience, it is known that few articles of prepared food in common use can be kept *when exposed to air,* by any single preservative substance or process.

It is also known that the *exclusion* of air is not *alone* sufficient to preserve changeable food substances successfully, because foods cannot be so collected as to exclude organisms; and the yeasts, moulds and bacteria which have been carried to their exposed surfaces in the dust of the air will develop fermentative and putrefactive changes, unless in addition to hermetic sealing the food is sterilized by sufficient heat.

Modern food preserving in its broader adaptation may be said to have had its origin in the discovery by the Frenchman, Appert, in 1804, that an article of food first heated, then hermetically sealed and sterilized, would keep practically as long as the seal was intact, without the use of chemical assistance.

One year later, De Heine, then in England, patented a process by which he claimed that food could be preserved by completely exhausting the air with an air-pump. All attempts at this, however, seem to have been unsuccessful, until a process discovered by one Wertheimer in 1839 came to be used. This provided that the food to be preserved should be placed in tin or metal cans, the interstices being filled with water, juices or other fluid, and the lid to be securely sealed. The cans were then set in water and boiled, the air being expelled through small holes pierced in the lids. When the food was sufficiently cooked and the air entirely driven out, the holes were filled with solder, completing the process. Food thus treated would remain in a perfect state almost indefinitely. No very great improvement, other than the elimination of solder in the sealing of tin containers, has

since been made upon that method and no change at all in principle. And, while the *theory* of these men differed from that accepted by modern science, the same *means* are used and the same results obtained as to-day; the process here described being used in all large canning factories in America, as well as the countries abroad, and in principle at least, practised in every household in which fruits and vegetables are preserved.

Although Appert's discovery was made more than one hundred years ago, it is only within comparatively recent years that its commercial value has been so fully appreciated as to cause its extensive employment in a commercial way on the American Continent, at least.

The early influence of the discovery was quite marked, however, in the home kitchens of our thrifty forebears in the New England and Middle States, where, with ever increasing skill in cookery as generation followed generation, a high degree of success came to be attained in the preservation of the fresh fruits and vegetables of the harvest season for winter use.

The products of these home kitchens were many and varied. Their appetizing qualities were due to the excellence and freshness of the material employed; their keeping qualities were in proportion to the skill and exactness of their preparation and the cleanliness with which it was surrounded. No artificial chemical anti-ferments were known to our grandmothers and none were required in their preserving work.

" Preserves " was then a word to conjure with. It stood for the sole delicacies of a large proportion of the whole nation. It was the embodiment of feasting and good cheer. It lent an especial significance to holiday dinners and " company " suppers. It calls up to-day, visions of mothers and grandmothers, busy as bees in roomy kitchens, their faces aglow with the heat of their work and their pride therein; surrounded by pans and baskets of luscious and toothsome products of farm and orchard, and by the most tantalizing odors that ever assailed the nostrils of unappeasable youth. It brings to us visions of rows of enticing jars and bottles on high, forbidden pantry shelves; of moments of fond maternal yielding to insistent and flattering persuasion, and exciting conjecture as to what delicious jam or preserves would be forthcoming when the minister suddenly appeared at supper time.

But, with the passing of time, the old fashioned manner of living changed. The increase of wealth increased enormously the demand for luxury in living, while the gathering of the population in cities brought about a congestion which made the former method of supplying the food demand wholly inadequate, and it was with the coming of these conditions that the manufacturer of prepared foods entered upon the scene, to become one of the great factors in the nation's progress.

And it may be said, and I wish to emphasize this in passing, the principles and practices of these old-time home kitchens furnish the best traditions that govern the preserving industry of to-day. It is as true now as then, that the best results in product can only come through the employment of good material, the maintenance of a high degree of sanitation and the application of conscientious skill; and this, regardless of whether the work is performed in the home or the great commercial kitchen, but the demand upon the modern commercial kitchen in the way of almost infinite variety, makes these requisites to a high degree of perfection, doubly essential.

While the canning trade—that branch of food preparation which shows the most remarkable expansion—had its origin, as has been stated, more than a hundred years ago, it was not until a comparatively recent date that the canning business assumed the dignity of an industry and entered upon the era of expansion that has carried it to its present vast proportions, amounting, it is estimated, to an output of more than sixty millions of dozens of the three leading vegetables—tomatoes, peas, and corn—during the last season; not to mention the other millions of dozens of meats, vegetables, fruits, and miscellaneous foods.

I shall not indulge in statistics, because figures in this connection are too bewildering to convey a comprehensive understanding. To speak of a quantity of ten millions of bottles or twenty-five millions of cans is simple enough as a mere statement, but the actual quantity itself, resolved into an existing fact, is inconceivable to the average mind not trained to think in millions.

In the early days of the commercial food preserving industry, the manufacturer confined himself to a very few articles which, although honestly enough made, were more or less indifferent in quality. With improved facilities, however, his skill in cookery

gradually increased and with it the volume of his business; a development through which the food resources of the world have been wonderfully augmented, affecting not only our own methods of living, but changing the restricted diet of the Polar Regions and the Tropics to the bounty of the Temperate Zone.

For, in this progressive age, it was inevitable that this question should arise—as arise it did—" Was it not possible to duplicate, nay, to improve upon the time and man honored products of countless kitchens and skilful housewives; and to place them on the general market within the reach of all who wished to taste their delights?" It was possible and it was done. Prepared foods have grown in number until there is now estimated to be about five hundred, and through this growth the laboring man of to-day may, and does enjoy food luxuries which, fifty years ago, the rich could hardly obtain.

In the meantime, the business offered an inviting field for the not over-scrupulous manufacturer. It was found that inferiority of raw material, imitation and adulteration, artistically colored and thoroughly embalmed with artificial preservatives, could be so concealed beneath a veneer of attractive appearance and fanciful labelling, as to obtain a ready and profitable market; and, as evil always seems to be endowed with more vitality and spreads more rapidly than good, the evil of adulteration and inferior food preparation swept over the country like a prairie. fire. That peculiar trait of the American people which is called " The bargain counter mania," afforded the unscrupulous manufacturer an outlet for his lower priced product; cheapness became the goal of his ambition and this ambition was realized and the goal reached by placing upon the market, not only products which contained not a single drop of the ingredients of which they were supposed to be made, but products having no other claim to merit than to pay a profit to the manufacturer who produced and the dealer who sold them.

Such practices could not long exist, however, in a civilized community without attracting the attention of scientific men interested in the public health and welfare, and, out of the discoveries made by these men, came the agitation which finally led to the enactment of better State and National Laws for the protection of the people in this vital matter.

That the National Law has brought about a revolution in some directions, no one will deny. There is certainly less cheapening adulteration going on—less misrepresentation and deception; but there still remain many abuses to be corrected, chiefest among these, I believe, the continued tolerance, by compliant authorities charged with the administration of the law, of artificial preservatives.

The rapid growth of the preserving business in its early stages attracted much capital without corresponding experience, and in such cases, for the most part, business disaster was only averted by the extensive employment, in nearly everything produced, of chemical anti-ferments, which served as a protection against all the mistakes of cooking, sealing, and sterilization, and obviated entirely the necessity of proper sanitation either in methods or surroundings.

The first objection to their use, however, and, I believe the most glaring abuse that exists to-day, lies in their employment for the purpose of preserving partly spoiled and ill-cared for vegetables and fruits.

The principal substance that is used for the artificial preservation of vegetable and fruit products, as well as for meats and fish in some cases, is the drug, Benzoate of Soda—which, in its least objectionable form, is a tasteless and odorless derivative of coal-tar.

It is not my purpose to discuss here the extent to which the substance, Sodium Benzoate, itself, may be harmful. That is a scientific question, the discussion of which I am willing to leave to scientific men, confining myself rather to a few brief words concerning its possible significance in food products.

But, before proceeding to this phase of the artificial preservative question, I would like to call attention to the fact that the weight of scientific evidence, especially on the part of the medical profession, is strongly opposed to it and to suggest that if there is a doubt about the amount of injury that it causes, the people and not the manufacturing interests who desire to continue its use as a means of securing a greater pecuniary profit should have the benefit of that doubt.

As I have said, however, it is rather the possible significance of artificial preservatives in modern food manufacture, than their

own injurious nature, that I wish to touch upon. You may call it, if you please, " The Moral Side of the Artificial Preservative Question."

Let me state at the outset that every product of fruits and vegetables with which I am familiar can be successfully made in a commercial way, without artificial preservatives. This is evidenced, beyond dispute, by the fact that the entire product of at least twenty-five, and probably more, leading American food preservers is entirely free from these substances.

Why, then, should any one wish to continue their use? Commercial cupidity, my friends, yields very grudgingly to attempted reform. There is cannery waste to be worked up profitably into ketchups and soups—skins, cores, and decayed parts of tomatoes, cooked up and thrown into barrels to be shipped about the country for use as wanted. There are always job lots of spoiled or partly spoiled fruits and other similar materials lying about in the season that can be picked up cheaply. To say nothing of the expense attending its proper disposal, it is hard to send such material to the sewer when profit can be gained from it by sufficiently dosing it with a chemical preservative to protect it from putrid fermentation, and then disguising its taint with spices and flavors until it really becomes quite presentable and in some degree acceptable to those who do not discriminate very closely in favor of quality and who are only slowly learning the significance of the legend on the outside of a package : " Preserved with $1/_{10}$ of 1 per cent. of Benzoate of Soda."

While the demand of the reactionary manufacturer for the continued tolerance of some kind of an artificial preservative is based upon several reasons, the principal pressure in its favor comes from users of tomato waste which has a commercial importance not generally understood.

Tomatoes are probably more extensively canned than all other summer vegetables put together—and all the canning is done in a period of six to eight weeks, under high pressure.

Tomatoes are also more extensively used in soups, condiments, sauces, etc. than any other fruit or vegetable—the consumption of tomato ketchup alone running into many millions of dozens annually.

In canning tomatoes, the canner's first and best attention is naturally to his principal product, and it may be said that it is

generally a most worthy product; but there is a great amount of waste—skins, cores, and decayed tomatoes—which there is neither time nor inclination to care for and which falls under foot disregarded as it accumulates.

Hundreds of thousands of barrels of this refuse are made in a season. It is pulped and put into the barrels under conditions that would better be left to the imagination than described, and then chemically " preserved " against actual putridity. It is safe to say that no one would ever again desire to eat any benzoated article after once seeing this material and its treatment.

This tomato refuse is sold at about $1.00 to $3.00 per barrel, to be made into tomato ketchup, soup, baked bean sauce, etc., which are eventually labelled as made of fresh, ripe tomatoes, and which carry only one protection to the consumer namely, a statement of the presence of the preservative on every label, which is put there under one of the occasional beneficent food regulations of the Agricultural Department at Washington, but it is always printed as small and obscurely as possible. Thus the consumers' only protection is to read all food labels carefully, including the fine print.

Such goods are extremely profitable, being sold at only a trifle less than goods made of the best raw materials, and it is really around the tomato waste industry that has rallied most of the effort for the nullification of the Pure Food Provisions of the National Food and Drugs Act.

A term much employed by the pro-preservative interests in their defense is " concealed inferiority " and elaborate arguments are set up to show that the addition of a chemical preservative to rotten tomatoes or fruit, for instance, changes neither the odor nor flavor of the material—while, as our friends proceed to show us, vinegar, sugar, salt, and spices will disguise unpleasant odors and flavors; and then they proceed to vigorously attack the use of the time-honored condimental preservatives, but there is a maxim as ancient as the time of Democritus which reads: " Whatever pleases the palate nourishes." Modern science has proven the truth of this maxim and has given us acceptable reason why condiments are necessary; why they are used by all castes, races, and civilizations. Acting principally upon the nervous system through the sense of smell, condiments stimulate the flow of both the saliva and the gastric juices. They materially aid

digestion, and the familiar phrase, " to make the mouth water," states a physiological fact.

And, unfortunately for the line of argument of the reactionaries, nobody contends or ever has contended, that Benzoate of Soda "conceals inferiority." Being tasteless and odorless, it has no more effect in that direction than would have so much cornstarch or wheaten flour. The expression "concealed inferiority " is simply one coined by the friends of chemical preservatives as a premise upon which to build false argument.

Artificial preservatives do not conceal inferiority, but they do permit and encourage disguised inferiority and the grossest fraud.

With artificial preservatives permitted, commercial cupidity is further aided, not only by the elimination of all need for factory sanitation and care in cooking, but as much water may be left in, to further cheapen the product, as suits the convenience of its maker. Also, bottles and other containers need not be washed and sterilization becomes a useless expense.

I have no hesitation in saying that the principal use of Benzoate of Soda and like substances in modern food manufacture to-day is either to permit the use of a lower grade of material, or carelessness in process. Its tendency is to lower quality in some direction all the time and to invite actually unwholesome practices, and the question of whether we are to have cheapness in our foods at the expense of quality and wholesomeness is as much alive to-day as it was before a Food Law was placed on the Statute Books.

We are turning the light into the obscure and unsanitary bake shop. We have cleaned up the meat packing establishments and deprived them of their artificial preservatives. It is high time that better attention should be given to the vegetable and fruit preserving industries, and that by the withdrawal of the temptation furnished by this mischievous preservative substance, permitted not by law but in spite of the law, we can come to feel that we are secure in eating only those things which we would readily eat if we saw them made and saw the material entering into their composition.

The modern manufacture of foods that are pure in the best and strictest sense, however, the really modern, up-to-date factory is not a place of gloom, dirt or mystery. And the underlying

purpose of the progressive manufacturer is to give the public
the choicest products so prepared and packed as to offer at a
reasonable price, the highest attainable degree of quality, purity,
and cleanliness.

The chief reliance of the better class of food preservers is
sterilization. In the preparation of foods by canning, preserving,
etc., the most essential things in the processes are the steriliza-
tion not only of the food, but of all utensils and the careful sealing
of the sterilized food to *exclude* all germs, because, as has been
shown, both air and water contain bacteria and yeasts and may
contain mould spores; and both foods and all utensils used in
the process of preserving foods, are liable to be contaminated
by these organisms. For this reason the appliances, as well as
the food, must be sterilized until all life and sources of life in
and about them have been destroyed.

Most of the appliances of the modern food factory are auto-
matic. The direct personal contact with foods by human hands
is discouraged and reduced to a minimum; and, where unavoid-
able, it is a modern practice that all who are engaged in work
requiring this, shall have their hands frequently inspected and
at brief intervals subjected to a thorough manicuring service.

Where kettles are used, the material is usually of burnished
copper and they are provided with steam jackets which permit
the application of high degrees of heat without scorching and
of perfect, instant regulation. Conveying pipes for liquids are
usually silver lined to prevent the action upon them of fruit
and vegetable acids and the sterilizing appliances, both for con-
tainers before putting them into use and after filling, are the
best that scientific skill can devise.

The doors of such great modern commercial food kitchens are
nearly always wide open to visitors, to permit the freest possible
public inspection of both materials and methods.

Those who cherish the belief that the kitchen of some vigilant
and ultra-fastidious New England relative embodies the highest
degree of spotlessness possible to human achievement, freely
admit, after seeing both, that in the modern commercial kitchen,
even she, with all the honor that is her due, has been outdone and
surpassed.

In the invitation extended to me it was suggested that I
present some illustrations—a suggestion which I accepted some-

what hesitatingly, because the only readily obtainable views for use in this manner would of necessity be from the establishment with which I am personally connected. However, they are for the most part only typical of what exists in many other similar establishments.

Fifty-four lantern slides were then shown illustrating the growing, gathering, and preserving of vegetables, the harvesting of olives and the preparation of olive oil, and the process of preserving the various fruits from the fresh product to the sealed can.

The speaker closed with the following remarks:

Thus you will have seen that the modern commercial pre-serving idea is, in all essential respects, that of the housewife of long ago. The fine, old, home-made idea. The housewife selected her fruits and vegetables with anxious care, choosing only the best, as befitted so important an occasion as the preserv-ing season. In her snowy kitchen, she prepared them and put them up according to time-honored recipes. This is the modern, up-to-date preserver's idea precisely, in its primitive fundamen-tals, but it is improved upon vastly. He goes forth into scores and hundreds of gardens and orchards, and he too, selects the best and discards all else. He, too, works in snowy kitchens, but in kitchens where cleanliness is enhanced by sanitary precautions and appliances beyond the housewife's reach; and the recipes upon which his work is conducted are simply the good, old-fashioned, housewifely kind, but improved and refined by the best work and thought and experiment that capital can supply or painstaking care obtain.

Hypochlorite Treatment of the Omaha Water Supply. JAY CRAVEN. (*Eng. Record,* lxiii, 128.)—This article shows the efficacy of settlement followed by hypochlorite treatment in remov-ing bacteria from the water supply. The water is first pumped into sedimentation tanks and allowed to settle. When the water is very turbid, aluminum sulphate is used as a coagulant. This sedimentation reduces the bacteria 97.4 per cent. The settled water is then treated with hypochlorite, in the proportion of 0.3 parts per million of available chlorine, ranging to 0.35 or 0.4 parts per million according to conditions, which gives a further reduction 93.3 per cent. in the bacteria in the settled water, making the total reduction in bacteria 99.83 per cent.

NOTES ON THE DESIGN OF CENTRIFUGAL PUMPS.

BY

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A CONSIDERABLE degree of uncertainty and confusion of ideas appears to exist in the design of impellers for a given discharge. The average designer in determining the width of the impeller b, Fig. 1 is generally guided by the nearest available precedent with a result often at variance with expectations, and it it is not at all uncommon to find pumps yielding a discharge 30 per cent. or 40 per cent. " short " of the specified capacity.

Although many articles have been written devoted to the subject, none of them gives the designer any immediate help in solving his problem by presenting a reliable theory in a concise form. The problem is generally as follows: *Given the total*

FIG. 1
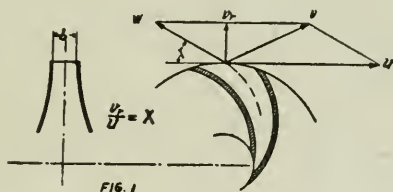
head, the speed and the discharge, to find the proper diameter and the width of the impeller.

Practice has shown, that, regardless of other requirements (such as the flatness of the efficiency curve, the variation in the shape of the horsepower curve according to a certain prescribed law, etc.) the discharge is subject to certain definite rules that can be easily understood and applied, viz.:

1. *The ratio of the radical velocity, Ur, to the peripheral velocity, U, for a given type of pump working under favorable conditions is a constant, X, so that $Ur \div U = X$ Fig. 1.*

2. *By plotting efficiency curves for various speeds in the discharge-efficiency diagram, it will be noticed that the points of maximum efficiency of each curve fall nearly on a straight line, hence the constant, X, varies but little with the speed.*

3. *The use of "radial velocity" alone as a means of deter-
mining the width of the impeller will always lead to error. A
correct value of the radial velocity cannot be prescribed and is
seldom correctly assumed.*

The latter method is apparently customary with designers
and, it is said that nine pump builders out of ten include in their
quotations the cost of an extra impeller, it being quite out of the
question to "guess" at the correct shape without a trial.

The general tendency to make the width of the impeller
excessive is scarcely justified by the results of such practice. It
may increase the *pressure* but only with a considerable loss of
efficiency. The fault mainly lies in the suction ends of the
blades. Many an impeller in which the suction tips of the blades
were very carelessly designed would not admit the desired amount
of water into the impeller. A well-known pump designer has
stated that he advocates radial blades at the entrance, this shape
being "just as good as any," a procedure scarcely in keeping
with fundamental laws of dynamics.

Assuming, however, that the suction elements of the blades
are correctly designed, the various values of X as given by both
theory and practice may be considered by an examination of the
following examples:

Ex. 1. Impeller approximately 20 inches in diameter, speed 870 R.P.M.
Efficiency *excellent*. Angle of the blade with tangent at discharge 48 de-
grees. $X = 14$ per cent.

Ex. 2. From M. R. Tison's article in *Revue de Mécanique,* Oct. 31,
1909, X appears to be 17.4 per cent. for blades inclined at 45 degrees to the
tangent and 19 per cent. for blades discharging radially.

Ex. 3. Electrically driven pump of 30,000,000 gallons daily capacity.
Diameter of impeller 37⅜ inches, width 5⅞ inches, efficiency *excellent*. X
approximately 12 per cent.

Ex. 4. For roughly designed common pumps, X is often 10 per cent. to
12 per cent. For marine work, bilge pumps, etc., from various pocketbooks,
X appears to be much lower, about 6 per cent. to 8 per cent. A higher value
would undoubtedly increase the efficiency.

Ex. 5. Mr. Charles H. Innes in his book on centrifugal pumps, in com-
paring the results of his theory with Prof. Unwin's experiments, uses the
formula U (radial velocity) $= \frac{1}{4}\sqrt{2gH}$ and, since the peripheral velocity
for blade angles of about 30 degrees is close to $\sqrt{2gH}$, the ratio X appears
to be about 25 per cent.

Ex. 6. In Prof. Rateau's high speed pump, the impeller is 3⅛ inches in
diameter, width ¼ inch, speed 18,000 R.P.M., capacity 190 G.P.M. against
863 feet head. Efficiency, *good*. X about 7.4 per cent. These proportions

may be correct for so high a speed and so small an impeller, but not for lower speeds.

Ex. 7. Single-stage pump. Impeller 8 inches in diameter. $X = 8\frac{1}{2}$ per cent. Efficiency *rather poor.*

Ex. 8. Multi-stage pump. Impeller 24 inches in diameter. Speed 870 R.P.M. Capacity 1950 G.P.M. $X = 8\frac{1}{2}$ per cent. Efficiency, *rather poor.*

Ex. 9. Multi-stage pump. Impeller 31 inches in diameter. Capacity 3000 G.P.M. $X =$ a little over 11 per cent. Efficiency *good.*

Ex. 10. Single-stage pump. Impeller 14 inches in diameter. $X = 12.2$ per cent. Efficiency *good.*

Ex. 11. From experiments made at the University of Wisconsin (Madison, 1909) it appears that the best efficiencies were obtained at $X = 14$ per cent.

Ex. 12. Single-stage pump. Impeller 18 inches in diameter, 1184 R.P.M. $X = 14.2$ per cent. Efficiency good.

Ex. 13. From Dr. Grünebaum's book on pumps (Berlin, 1905) for radial blades, X appears to be 23 per cent.; for blades inclined at 31 degrees to the tangent, $X = 21.5$ per cent.

Ex. 14. From Prof. Boulvin's "Cours de Mécanique appliquee aux Machines" 7e fasc., p. 122 (Paris, 1897) $b_1 r_1 = \dfrac{Q}{2\pi} \; \dfrac{1}{\sqrt{sin\,\gamma\,(1-sin\,\gamma)}} \; \dfrac{1}{\sqrt{gH}}$ where b_1 is the width and r_2 the radius of the impeller (all in metres), Q is the capacity in cubic metres per second and γ is the angle of the blade with the tangent at the discharge, so that for discharge angles near 30 degrees and peripheral speeds approximately $= \sqrt{2gH}$, the ratio X will be found to be about 35 per cent. This is rather high. In fact all theoretical values of X seem to be much higher than the results of good practice.

Ex. 15. Prof. Church's book on "Hydraulic Motors" (1905, p. 177–178) does not give any formula for X but it can easily be derived by elimination of Un from equations 6 and 20. The result is $X = \dfrac{Vn}{Un} = (1 - sin\,\delta)\,tan\,\delta$. Thus for 12 degrees, $X = 16.8$ per cent.; for 30 degrees, $X = 29$ per cent.; for 45 degrees, $X = 30$ per cent.

Ex. 16. From the two examples given by Dr. Lorenz (*Z. ges. Turbinenwesen*, July, 1906) (*a*) Impeller $15\frac{3}{4}$ inches in diameter, speed 620 R.P.M., angle of blade with tangent 56 degrees; $\dfrac{2gH}{U^2} = 1.28$; $X = 36.3$ per cent. (*b*) Impeller $15\frac{3}{4}$ inches in diameter, speed 1000 R.P.M., angle of blade with tangent 151.5 degrees (curved forward).

Mr. Hanocq, of the University of Liege, in his most remarkable paper on centrifugal pumps (*Revue Universelle des Mines et de la Métallurgie,* March and June, 1909) gives several curves showing the dependence of the efficiency upon the value of X. One of his examples has been worked out for a discharge angle of 30 degrees and a suction angle of 35 degrees.

The writer has worked out a similar example for a 12-inch impeller having a discharge angle of 30 degrees and a suction angle of 16 degrees 20 min. The results are plotted in Fig. 2. The curve C gives the ratios $\frac{2gH}{u^2}$, u being the peripheral velocity and the curve R represents the theoretical hydraulic efficiency. These curves have been plotted for a pump having a *properly*
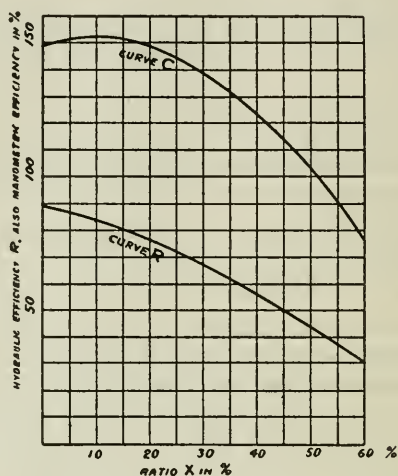
FIG. 2

designed *diffuser*. For centrifugal pumps without diffusers, the curves would be entirely different.

The following conclusions may be then drawn: *There is no advantage in excessive width of impeller. Great care must be exercised in designing the suction elements of the blades. High speeds are consistent with good efficiency. The best values of X lie between the narrow limits of 12 per cent. to 15 per cent.*

INTRODUCTION TO CERTAIN FUNDAMENTAL PRINCIPLES OF MODERN PHYSICS.

BY

PROF. NERNST.

(Translated from the *Revue scientifique*, by W. J. Williams, F.I.C.)

EXPERIMENT AND GENERALIZATION BY HYPOTHESIS.

We can assign as the immediate and common aim both of physics and chemistry, the furnishing, in the greatest possible number of cases, of as complete and as simple an answer as possible to this question: Given, the operation of a system (of finite dimensions) what phenomena will be produced, and what will be the condition of the system at a definite period? To solve this problem, it seems to us indispensable to first realize the system, the future of which we wish to learn, and to study its history. The success of this attempt will depend on the ability of the observer, and on the means at his disposal, and this success will increase with the progress of experimental skill.

But the infinite variety of interesting systems which nature presents, and further, the immense labor which must be expended for a fruitful exploration (for it is not alone a single system undergoing transformation) would be enough to discourage the physicist, and make him recoil before a systematic study of the phenomena of nature, if we could not add to the ideas immediately apparent to the senses, other ideas conveyed by a valuable auxiliary. This auxiliary is to place the theoretical value on the experiments made on several systems, and consists in referring to a second system, by analogous reasoning, the observations made on the first system. If we have studied the phenomenon of the fall of a heavy body on one point of the earth's surface, we can refer some of the facts observed directly to other systems, *e.g.,* to the fall of a heavy body at another point of the earth's surface. The skilled glance of the physicist discovers and recognizes whatever there is in common in phenomena of quite different appearance, and his success is so much the more brilliant, the greater these differences appear.

The application of the observations made in one case to

another case, cannot be done without some uncertainty; but, by repeated verification experiments, it acquires a greater and greater probability, until it finally reaches the rank of an *empirical natural law.* For example, the discovery of such a law as that which enables us to calculate the specific heats of solid combinations by the help of certain numerical coefficients, the atomic heats of the elements, is an undoubted advance; so much the greater because this law includes many experimental facts, and has led to the foreseeing of others.

The history of the physical sciences teaches us that we can discover a new natural law by two essentially different methods, one of which may be called the empirical method and the other the theoretical. In the first method one endeavors, by experiments directed to that end, to collect a number of observations, expressible mathematically as far as possible, on the phenomena between which a relationship is suspected, and then to compare the results obtained. In this way it was discovered that there were certain relations between the properties of the elements and their atomic weights. On the other hand, the second method leads by logical ideas on the nature of the phenomena and a purely speculative activity, to a new conception, the correctness of which should be verified by experiment. In this way the law of chemical mass-action was found by kinetic considerations on the combination and dissociation of bodies which react on one another.

Of the two methods the first can be followed in all cases, and it always leads to certain results, although, it is true, only after very exacting work. As for the value of a natural law thus obtained, it is chiefly the extent of its application that gives the measure of its importance; and the consideration accorded to it should be so much the greater, the more numerous and the more varied are the phenomena to which it applies. Thus the principles of thermodynamics furnish us with the most brilliant example of the empirical discovery of a natural law, for they apply to all the phenomena of nature, and should always be taken into consideration in all scientific researches. On the other hand, such a law, whose domain is so vast, is much more difficult to understand, and demands much more skill in handling it, the more general it is in its application. In the above case the difficulty in applying the law exactly and completely to a given

natural phenomenon is sometimes so great that the scientific application of general principles to a particular case should be considered as a true advance, although the result obtained by the utilization of the more general principle actually contains nothing absolutely novel.

However great the importance this purely inductive method of research may have had in the past, and always will have, in scientific progress, nevertheless undoubtedly we shall penetrate more profoundly into the essence of these phenomena, when by the second method, based on accurate ideas and their logically deduced consequences, we arrive at a new law of nature; and that is why this method appears the most attractive. It is obvious that we can follow it successfully only on the condition that we have made a fortunate choice of the ideas which are the basis of our theoretical reasoning. But it frequently happens that it is impossible to put these fundamental ideas to the test of experiment, and to verify their value; then the investigator who allows himself to follow the deceptive gleam of badly chosen fundamental ideas is incessantly in danger of ending in error.

Such conceptions, more or less impossible of experimental demonstration, are called *hypotheses;* such is the admission of the existence of a luminous ether filling the universe, an imponderable mass, which on that account escapes our senses, connected with ordinary matter; again such is the supposition that all bodies are composed of indivisible though finite particles, but extremely small, which on account of their minuteness, cannot be directly perceived by our senses. The introduction of hypotheses is, as we have said, absolutely necessary for a knowledge of the phenomena of nature deep enough to lead us to the discovery of new laws. As these can be submitted to experiment, the result shows not merely the truth, but also the value of the hypothesis; since one failure would demonstrate not only the inapplicability but also the falsity of the hypothesis from which we started.

Thus hypothesis is a very important aid to science; it is not the goal (at least for those who apply themselves to the study of nature) but it is considered to justify its existence by serving as a bridge to connect together the already known facts of experiment and to link them to new facts. The value of a good hypothesis consists essentially in deepening and enlarging our

knowledge of phenomena, that is to say, it serves as a natural law. If at all times, though in different degrees, human nature has always shown a predilection for hypothesis, it is due to the fact that the knowledge of a new law gives more satisfaction if it has been derived by the deductive method from general points of view, than if it had been deduced, by the inductive method, as the consequence of long and exacting experiments.

To resume, we say that from the side of experimental work, that is to say, the observation and the quantitative study of phenomena, the special activity of the investigator should be principally directed to the discovery of the most general laws and the most workable hypotheses. The expression, whether in ordinary language or in formulas, of theories found by the speculative method, has on the one side the advantage of allowing others as well as the discoverer to take part in their verification; and on the other side, the scientist who has taken cognizance of a new theory, which is susceptible of general application, can forsee a multitude of the details of its phenomena.

" He who knows the law of phenomena has not merely acquired knowledge but also the power of affecting, as occasion arises, the course of nature itself and making it work according to his will and to his advantage. He sees the future progress of these phenomena. In fact he possesses those powers, which in the age of superstition were looked for in the Magi and the prophets." (Helmholtz, *Goëthe-Rede,* 1892.)

To-day, we are in possession of a certain number of experimental laws and hypotheses susceptible of the widest application to different branches of the natural sciences, the didactic exposition of which should properly precede that of the sciences themselves; this is particularly true of pure physical chemistry. In fact, the principle of the indestructibility of matter owes its clear and full expression to chemical research; the principle of the indestructibility of energy gave birth to a new branch of chemistry, thermochemistry; and the principle of the transformation of heat into external work (the second principle of the theory of heat), is nowhere shown to be more fruitful than in its application to chemical phenomena; lastly, the hypothesis of atoms and molecules seems indispensable for the complete comprehension of the nature of chemical combinations.

SPHERE OF THE VALIDITY OF THE LAWS OF NATURE.

It has frequently been admitted that a natural law should have an absolute value; to-day it is difficult to accept such an opinion; at least everything points to the fact that no natural law exists of such vast extent. It seems rather that all the laws of nature have a more or less extended value, and that there is always a limiting case where the law fails.

Thus, to give an example, we have serious reasons for thinking that the second principle of thermodynamics would fail if applied to very small quantities of matter. But it is evident that it would not be reasonable, in this case or in similar cases, to elevate this proposition to the rank of a law of nature; let us say rather, in a general way, that the question is not one of knowing whether a law is rigorous or not, but rather of knowing between what limits it can be applied. This idea is perhaps not without importance with regard to certainty (exactness) in scientific research. For it often happens that the progress of science makes it necessary to revise certain long accepted laws; and sometimes we hear allusions to the fallibility of human research. But on looking closely into the matter, we always find that the disputed law has preserved its value to a large extent, and that the progress of science has merely fixed the limits of its legitimate application more precisely. It may even be said that, since the development of the physical sciences, there has not perhaps been one law established by a talented investigator, which has not always kept a vast domain where it remains applicable; or which, in other words, has not remained a natural law applicable within certain limits.

Thus it cannot be said that the electromagnetic theory of light, the old optical theory established by Fresnel and his successors, has lost its importance; on the contrary, lately, as in earlier times, the old theory has explained a multitude of phenomena perfectly. It is only in certain cases that it fails, and there exists a series of relations between the optical and electric phenomena which were not foreseen. It follows from these that the electromagnetic theory of light realizes considerable progress, without belittling the importance of Fresnel's theory.

Instead of physical theories falling like autumnal leaves in the course of ages, it seems rather that, within certain limits,

they have eternal life; every new law which has been accepted by its eminent contemporaries will doubtlessly, in its future developments, have to submit to certain limitations, but none the less it will remain for all time the synthesis of a certain sum of truths.

SYSTEM OF MEASUREMENTS.

As we have already said, it should be the constant effort of the physicist to deduce from his observations the numerous facts that are verifiable by observation. The description of a phenomenon is often very difficult, when it furnishes no data as to the degree of greatness of the actions observed.

The units of measure were established at first quite arbitrarily, and for reasons more or less of a practical or historical nature. This refers to the fundamental units of length, of mass, of time, and of temperature. The units of other dimensions, which the progress of physics has introduced in greater and greater number, might have been chosen arbitrarily in the same way. Let it suffice to recall the expressions: pressure of (a) atmospheres, luminous intensity of (b) candles, engine of (c) horsepower, heat of combusion of (d) calories, etc.

A decisive progress was marked when Gauss (1832) and Weber (1852) showed, by the examples of electric and magnetic dimensions, that it was possible at least to limit this arbitrariness if it could not be suppressed. The method inaugurated by these savants consisted *in basing the new units on physical laws.*

For example, instead of comparing the intensities of electric currents with one another in any way whatsoever, and limiting themselves to relative measurements, they have adopted the reciprocal electrodynamic force of the currents as a basis for referring the intensity of a current to the aforesaid fundamental units; thus they have defined the unit of intensity of a current in absolute value, the intensity of a current of which two portions 1 cm. long placed on the same axis at a sufficiently long distance of L cm. exercise a repulsive force of $L^{\frac{1}{2}}$ upon each other, valued in mechanical units. The unit of resistance is the resistance of a conductor where the unit of current thus defined disengages in the unit of time a quantity of heat equivalent to the unit of work. The unit of electromotive force is defined,

by the help of Ohm's law, as the tension at the extremities of a conductor with a resistance 1 traversed by a current of intensity 1.

This method, which refers the new units to a small number of already existing units, and which replaces the simple comparison of the new dimensions by their value as a function of other dimensions, the units of which are known, is not, however, absolutely free from arbitrariness. In the preceding case, to define the unit of intensity they might just as well have chosen another form and another disposition of the portions of the current; thus, as Gauss and Weber have pointed out elsewhere, a system of electric measurements could have been established by using as a basis, instead of the electrodynamic phenomena, the electrostatic forces set in action at a distance by free electricity. In spite of that, it is evident that the principle of Gauss and Weber has considerably decreased the arbitrariness. What is still more important is, that by the introduction of the absolute system of measurements, the numerous physical laws take a very simple expression, on account of the disappearance of certain factors of proportion; and also that the absolute system summarizes for the physicist a mass of the details of knowledge, and gives the idea and the explanation of many particular circumstances in the kind of measurements applied to the most varied domains.

Besides one is in no way limited to the choice of the four fundamental units named above and generally employed hitherto; by the help of Newton's law of gravitation, mass can be expressed in functions of length and of time (Maxwell); by means of the equation for gases $p.v. = RT,$ by making $R = 1,$ the temperature can be expressed as a dimension of energy in mechanical units. For many reasons such changes do not appear advantageous, at least up to the present time, and it will be better to await the discovery of new natural laws before seeking to reduce the number of fundamental units. Naturally these would be chosen in such a way as to obtain great accuracy in the direct measurements; length, mass, time, and temperature meet this requirement well, but not energy, which for this reason cannot be considered as available for a fundamental unit.

THE INDESTRUCTIBILITY OF MATTER.

From numerous experiments we have learned that there is no variation of the mass of a body, neither from physical changes (*e.g.*, pressure, temperature, magnetism, etc.), nor from chemical transformations (the mass being measured, for example, by terrestrial attraction) (Lavoisier). A large number of chemical analyses and syntheses bear witness to the exactness of this proposition: notwithstanding the potent chemical phenomena taking place on the sun's surface, the action of this star on the planets does not change, an obvious proof that the total mass of the sun does not vary under the influence of these phenomena.

The question of knowing if the weight of the products of a reaction is equal to the sum of the weights of the reacting substances has been submitted to an exact verification by H. Landolt. He found that in fifteen cases examined the variation in the weights involved in the chemical reaction scarcely reached a few millionths and never exceeded the errors of weighing (0.03 milligrammes).

TRANSFORMATION OF MATTER.

The properties of a substance vary with the external conditions to which it is subjected; however, there is generally only a small variation of the physical properties corresponding to a small change in the conditions, particularly of pressure and of temperature. If, on the other hand, several different bodies, such as sugar and water, iron and sulphur, etc., are put in contact, even maintaining the external conditions constant, a great modification of their properties is produced, which goes so far as the formation of bodies which from several points of view are quite different to the original substances. Thus the same substance can assume, while the external conditions remain the same, quite different external properties,—matter undergoes transformation.

According to the observations made up to the present time, this variability of matter is confined to certain conditions. The law of the indestructibility of matter puts the first limit upon it, for the quantity of matter remains invariable during all these changes. Experience has provided us with another example in this sense: the results of numerous and difficult undertakings in the laboratory, from the attempts of the alchemists to trans-

form metals into gold, to the admirable syntheses of present-day organic chemistry, have taught us that it is even possible to transform equal weights of substances of a different nature from one to the other condition.

TRANSFORMATION OF ENERGY.

Second Principle of the Mechanical Theory of Heat.— Although the law of the conservation of energy has given us quantitative relations which always recur in the transformation of different forms of energy (external work, heat, internal energy) from one to the other, what is known as the second principle of the theory of heat has made known to us the limits to which the power of transformation of the different forms of energy must submit. From a purely qualitative point of view, this may be expressed as follows: *Exterior work, as well as the kinetic energy of masses in motion, can completely transform themselves in various ways from one to the other, and inversely; they can, similarly, transform themselves into heat* (perhaps the simplest way of utilizing the work is to put in motion masses of matter, which from the friction produce heat, while losing their kinetic energy); *but the inverse transformation of heat into work can only take place in limited proportions* (Carnot and Clausius' Principle).

The current of thought which leads us to seek just at what point the different forms of energy are transformable from one to the other, and to admit that there is a limiting physical law, is in reality the following: As fruitless as were the efforts of numerous inventors to construct a machine that would continually do work without the expenditure of energy to sustain the motion, so fruitful was the idea that these failures were due to a law of nature. On the ground fertilized by the lost illusions of the unfortunate inventors, a magnificent tree has grown, a knowledge of the law of the indestructibility of energy, the precious fruits of which Mayer and Helmholtz have gathered. But even to the inventor, perfectly imbued with the truth of this law of nature, the existence of a machine capable of doing work in the external medium and of yielding it without expense, did not appear an impossibility. According to the law in question, external work and heat are equivalent; they are two forms

of energy. But energy in the form of heat is abundantly distributed, in such a way that only an apparatus is needed to harness this energy and to return it to us in the form of work by making our machines go. For example, this apparatus could be plunged in a large reservoir of water whose immense store of energy it would transform into useful work; it would make the steam engines of our ships useless, for the screw would continue its rotary motion at will, at the expense of the inexhaustible quantity of heat contained in the ocean. Such an apparatus would also be, from a certain point of view, a *perpetuum mobile* (perpetual motion) in no way contrary to the first principle, but working conformably to this principle, deriving it from the heat of the exterior medium and restoring it in the form of work; this work, by its utilization, will reproduce heat (in this case by the friction of the ship and the screw) and the cycle would recommence anew.

Unfortunately this apparatus, which would make carbon useless as a source of energy, appears to be a chimera, like the *perpetual motion* of the inventors of the Eighteenth Century, who tried to create work from nothing; to say the least, numerous attempts have made this more than probable. We thus arrive, by the same method as for the first principle, by drawing up the balance sheet of so many useless efforts, at this proposition, *that an apparatus which could continuously transform into external work the heat of the ambient medium is in contradiction to a natural law, and is therefore impossible.* If the admission of this principle impoverishes the inventive spirit of man of one problem, on the other hand it enriches natural philosophy with a principle, the applications of which are almost inexhaustible.

This conclusion, which is primarily of a negative character, with the aid of certain reflections and by the help of certain experimental facts, serves to establish the quantitative expression of the law which limits the transformation of energy, and is known as the *second principle of the theory of heat.* The fundamental reflections which led to this principle have been clearly expressed by Carnot,[1] and this in 1824, which is remarkable because it was before the principle of the conservation of

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[1] Reflexions sur la puissance motrice de feu, Paris, 1824. Reprinted by Hermann, 1903.

energy was defined. To Clausius [2] belongs the immortal merit of having formulated this principle as an extraordinarily fruitful, universal law, and of having mathematically developed its consequences with exactness and universality.

Let us try to give the preceding proposition the form of a general principle of physics; the following ideas will serve:

I. *Every phenomenon which produces itself in a given system, that is to say, without the intervention of any form of outside energy, is capable, with the aid of suitable appliances, of producing a certain quantity of external work.*

By the term phenomenon, we mean every variation of a system, which causes it to pass from the initial state to a different final state. If an outside energy intervenes, the system can naturally produce a certain quantity of work; for example, an electromotor when supplied with a sufficient quantity of electric energy, represents, at least in principle, an inexhaustible source of external work.

The question now is to know what is the best method of utilization; that is, how to make a given phenomenon yield the maximum quantity of external work. For that it is above all manifestly necessary that the apparatus used should be as perfect as possible from the technical point of view, that it should work with the best practical effect, that care has been taken to avoid the loss of external work from secondary defects (friction or analogous occurrences, the imperfection of a badly fitting piston in a cylinder in which it compresses or expands gas or steam, defects of insulation in electrical conductors, loss of heat in thermal machines, etc.), but it is still more necessary that in every phase of the proceeding the force and the resistance to be overcome should be nearly equal. If the opposing force is the smaller, the change takes effect in one direction, if it is the greater it acts in the opposite direction, and as theoretically all losses should be avoided, it is obvious that the quantity of work obtained when the change is made in one direction is equal to that which it must expend to make it in the other direction. In such cases the action is said to be *reversible;* we shall see shortly cases in which this ideal can be indefinitely approached

[2] " Ueber die bewegende Kraft der Waerme," Pogg. Ann., lxxix, 369, 500. (Clausius has collected all the papers which have appeared since 1850 in a work entitled " Mechanische Waerme Theorie," Brunswick, 1876.)

(at least in principle). Let us admit that in general this is possible, and let us consider this proposition to be established:

II. *A phenomenon produces the maximum of external work when it is reversible.*

We can easily perceive that propositions I and II are in perfect agreement with the proposition that no appliance can continually furnish work at the expense of the heat of the ambient medium. According to I, since a phenomenon can only produce a limited quantity of work, such an appliance can only be a machine functioning in a periodic manner, which after a certain lapse of time returns to its starting point; according to II, this machine, in the most favorable conditions (with an ideal construction), has not, after a time, absorbed any external work, and in any case has not produced any, since it must function reversibly to avoid losses, and that at each motion in one direction it produces just as much work as it absorbs in the inverse motion.

As examples of phenomena which produce themselves, in the sense of proposition I, we might mention the fall of a stone on the ground, the mixture of two gases or two miscible liquids with each other, the diffusion and solution of a solid in a liquid, and, above all, the innumerable chemical phenomena which are produced spontaneously. The problem of determining the maximum of external work which can be obtained in each particular case, that is, in the sense of proposition II, the question of what means to use, to make a phenomenon reversible, is of the greatest importance, and its solution in certain special cases has led to discoveries of great importance.

Let us place two bodies of different temperatures in contact, then heat will pass from the warmer to the colder body; this phenomenon takes place spontaneously and no work has to be furnished; from proposition I it follows directly that in this exchange of heat, we must for one thing furnish external work to obtain the inverse phenomenon, that is, to make heat pass from a colder body to a warmer.

Clausius has enunciated this last proposition as a special principle: " Heat cannot pass from a colder to a warmer body without compensation, *i.e.*, without the help of an outside energy." But it is evident that this principle is only a particular case of a more general proposition.

To particularize these general explanations we can apply them to two particularly important cases, the first is that of the *isothermic* modifications, and the second is that of phenomena which *consist simply of the transference of heat* (equalization of different temperatures).

THE MOLECULAR HYPOTHESIS.

Although it appears extremely opportune to erect, on the basis of experimental propositions concerning the transformations of matter and energy, a doctrinal edifice in which the results of experience could be arranged in a methodical and obvious order, an hypothesis has been added to these propositions based on experiment, regarding the constitution of aggregate bodies. It was only at the beginning of the last century that this hypothesis, made in antiquity, was revived by Dalton and Wollaston and utilized to give us a clearer and deeper conception of chemical phenomena; it has since become, in a way, the principal guide in the development of physics and of chemistry. According to this hypothesis, an aggregate body does not fill the space which it appears to occupy; it is composed of very small but finite particles, more or less distant from one another, which are called *molecules*. That the interstices between these molecules escape us, that they are not more evident to direct observation than the molecules themselves, and that our senses rather indicate that matter *is* continuous, all these things are due to the minuteness of the molecules and to our incapacity of perceiving such small dimensions. This is not the place to examine whether the molecular hypothesis corresponds with the reality, or whether it does not owe its existence to our lack of power to attain a profound comprehension of the phenomena of nature by adopting other conceptions, or again whether by the development of the theory, we should not some day attain different and clearer ideas of matter; the time has not yet come to open such a discussion. One fact is certain, and that is the only important and decisive matter, that the molecular hypothesis is, in all the natural sciences and most particularly in chemistry, as great and as important an auxiliary as theoretical speculation has ever produced. That is why, in the account we are about to give of theoretical chemistry, we shall never lose sight of the molecular

theory; and shall make use of it in every case where the explanation of facts and clearness and quickness of expression, require it. Up to this day the molecular hypothesis, in its development, has furnished an abundant harvest and has enriched science with positive knowledge; why then shall we not direct our efforts to make our ideas of the world of molecules more definite, and arm our eyes with more and more powerful microscopes to enable us to consider it?

ATOMS AND MOLECULES.

The first great success of the hypothesis of the distribution of matter in separate masses was the simple and intuitive explanation of the law of definite proportions and of multiple proportions, propounded by Dalton, the discoverer of the law, who by this coup caused this hypothesis to be reborn for modern science, like a phœnix from the ashes of the old Greek philosophy.

From the point of view of the molecular hypothesis, the formation of a compound from its elements can be understood in the simplest way, as the combination of the smallest particles of the elements to form the molecules of the compound. It follows then that the molecules are divisible, and their division takes place when a compound is decomposed into its elements. Thus we are led to admit that the molecule itself does not completely fill the space it occupies in a uniform and continuous manner, but that it too is an aggregate of particles distributed in the mass of the molecule; these material particles are called *atoms*. The atoms which form a molecule are all alike, if it is a molecule of an element; but they differ, if they constitute a chemical compound. It is only in the first case that a molecule can consist of a single atom. The force which unites the atoms into a molecule is called chemical *affinity;* to the action of this force is attributed the reason why the properties of the atoms vary according to the molecular structure to which they belong, and why the properties of the compounds are often so different to those of the free elements.

Many experimental facts bear witness in favor of the view, which seems evident, that the atoms of the same element all have the same weight, and that the molecules of a simple chemical compound all have the same composition. Hence it is obvious

that the proportions by weight, according to which the different elements are combined in a chemical compound, are equally those in which they are combined in the molecule of the compound; but as this molecule contains a definite number of atoms, no matter by what process it was obtained, it follows that the composition is always perfectly definite. Further, the molecule can only contain whole numbers of atoms of each kind, numbers which generally are not very large; it follows then *that the proportions in which the elements are combined in the different compounds must be to each other as the atomic weights of the elements, or as simple multiples of their atomic weights.* Experiment perfectly verifies this deduction of the atomic theory; the proposition contains the law of definite proportions and of multiple proportions, and it greatly extends the experimental law by giving a precise and tangible idea of the purely empirical equivalents. In the meaning of the atomic theory, it is evident that the equivalents and the atomic weights must be in rational proportions; sometimes these proportions are not obtained without arbitrariness or without new experimental facts; and when we shall consider the determination of the atomic weights, we will indicate the methods which lead us to the values of the relative atomic weights, actually admitted to be exact (within the inevitable errors of observation).

CLASSIFICATION OF NATURAL PHENOMENA.

For a long time natural phenomena have been divided into *physical* and *chemical* phenomena; in the first the composition of matter plays generally only a secondary or subordinate rôle, whilst in the second the chief importance is laid on the changes in composition. Putting ourselves in the point of view of the molecular theory we see in the physical processes changes which leave the molecules intact; the chemical processes, on the contrary, cause changes in the composition of the molecules. It is clearly shown that this division is based on good and profound reasons by the very great distinction between physics and chemistry, both in the methods of work and of research, as well as in those of instruction; this is so much the more surprising because physics and chemistry pursue the same end, which is to reduce the complexities or the external world to the simplest

possible phenomena and laws. But such a separation does not appear to be fruitful for the future; at least that is generally admitted to-day, when physicists and chemists ardently work together on the borderlands of their sciences.

Since the propositions of the theory of heat claim to be applicable to all the phenomena of the external world, the question arises of knowing if it would not be possible to class these phenomena in a simple way, according to their thermodynamic qualities. In fact on examining the fundamental formula

$$A - U = \frac{dA}{dT}$$

we see at once that the following limiting cases demand attention.

1. $U = A$, *the variations of total energy and of free energy are equal.* Then the coefficient of temperature of A, and consequently that of U, are both zero, that is to say, that *the temperature has no influence on the phenomenon under consideration,* at least so far as concerns the thermodynamic properties. Inversely, if this condition is fulfilled, we have $A = U$. According to the way in which all these systems behave, whether they are acted on by the force of gravitation only and by the magnetic and electric forces, then the actions of these forces can be represented by a function of the forces (potential) independent of the temperature. Often, in chemical phenomena, A and U are equal, at least approximately.

2. $U = o$, then $A = T \frac{dA}{dT}$, where A *is proportional to the absolute temperature.* The expansion of a perfect gas and the mixture of two dilute solutions are included in this case, where the influence of temperature acts very simply (a gaseous thermometer).

3. The third limiting case, $A = o$ would give

$$U = - T \frac{dA}{dT},$$

that is to say, it can only be produced at a particular point of temperature. A can easily be very small in proportion to U in a sufficiently large range of temperature; and as in that case the coefficient of temperature of A would be very large, it follows in this case that temperature has a very great influence (for example, evaporation, fusion, dissociation, and in a word the " physicochemical " phenomena, properly so-called).

The third case is not of such striking simplicity, and has not given birth to such important hypotheses as the first case, which has introduced the attractive forces into science, and the second case which has been decisive for the molecular theory.

The cases $U = o$ and $A = o$ do not indicate any variation in the thermodynamic sense; but as such variations do exist in reality (the motion of a mass in a direction perpendicular to that of gravity, the change of an optical isomer to its optical antipode) and are even sometimes very important, thermodynamics only provides us with a very circumscribed means of classification for all the phenomena, although here it has been able to give us important points of view.

The Amount of Thorium in Sedimentary Rocks. J. JOLY. (*Phil. Mag.*, xx, 125.)—A determination of the amount of thorium in 34 different calcareous rocks gave a minimum of less than 0.03×10^{-5} and a maximum of less than 0.33×10^{-5} Gm. of thorium per Gm. of rock. Since calcareous rocks do not constitute more than 5 per cent. of the bulk of the sedimentaries upon the land, it is concluded that the influence of the surface materials in ionizing the air over calcareous districts cannot be directly inferred from these results.

Recovering Zinc from Galvanized Iron Scrap. ANON. (*Brass World*, vii, 11.)—A recent French patent claims the recovery of zinc from galvanized iron by placing it in a tumbling barrel or iron with perforated staves, revolving in an iron tank filled with a boiling solution of slightly basic zinc chloride. When the evolution of hydrogen ceases the barrel is removed and the scrap washed. Only a small amount of iron is dissolved, which can be precipitated by calcium chloride. The zinc goes into solution as zinc chloride. At the end the solution is highly basic and can be restored to the slightly basic condition by adding hydrochloric acid.

Cold Vulcanization. B. BYSOW. (*Zeit. Chem. Ind. Kolloide*, viii, 47.)—The sulphur chloride preparations were made by distilling the commercial product, collecting the fraction passing over at 136° to 138° C., and dissolving different quantities of sulphur in portions of this. The three preparations contained (1) 51.09 per cent. of chlorine and 48.91 per cent. of sulphur; (2) 46.40 per cent. of chlorine and 53.60 per cent. of sulphur; (3) 34.35 per cent. of chlorine and 65.65 per cent. of sulphur. Solutions of 5 grammes of each in 1 litre of dry petroleum spirit were used to

vulcanize pieces of sheet para rubber and the vulcanized samples extracted with acetone and analyzed. The results showed that Weber's theory, that in cold vulcanization the fixation of sulphur is dependent upon the extent to which the chlorine combines with the rubber, and the quantity of sulphur fixed is governed by the amount of heat generated by the combination of chlorine with the rubber, is untenable.

Resistance of a Concrete Building to Fire. ANON. (*Eng. Record*, lxiii, 137.)—A concrete building occupied by the Moser Paper Co., of Chicago, burned for four hours with only slight damage to the building, such as discoloration of the walls and ceiling and surface spalling at a few points. The material burned was a stock of paper stored on shelves and in wooden packing cases.

· **Study of the Fire-fly.** H. E. IVES. (*Elect. World,* lvi, 804.)— An investigation of the nature of the glow produced by the fire-fly indicates that the visible rays are the only ones emitted, except for the "body-heat" of 40° to 50° C. On this basis the luminous efficiency of the fire-fly is calculated to be 50 candlepower per watt, as compared with 2 to 3 candlepower per watt in the most efficient of the electric arcs.

Discovery of a New Star. G. RENAUDOT. (*Rev. Gen. des Sciences,* xxii, 50.)—Mr. T. E. Espin, of Durham, England, discovered a new star on Dec. 30, 1910, in the following position R.A. 22hr. 32′ 9.5″. Decl. + 52° 15′ 21″ in the small circumpolar constellation of the Lizard, in the Milky Way. Its magnitude is 7.5. It is in excellent position for observation in northern latitudes, and is easily recognized by its very characteristic red color. Spectral analysis reveals four particularly brilliant lines in the red, the yellow, the blue-green, and the blue. The red line of hydrogen is the most intense.

Production of Zinc (or Tin) and Titanium Alloys. (A Patent by A. J. ROSSI, Niagara Falls, N. Y.)—A zinc-titanium alloy is produced by adding titanic acid, alone or with zinc oxide, to a molten mixture of zinc and aluminum, and heating to a temperature sufficient to insure reduction by means of the aluminum. By the use of tin and tin oxide in place of zinc, a tin-titanium alloy can be obtained.

Standard of Electro-motive Force. E. WARBURG. (*Rev. Gen. des Sci.,* xxii, 94.)—The Physikalisch-technische Reichsanstalt, has adopted, since Januaray 1, 1911, the value of 1.0183 international volt, at 20° C., as the electro-motive force of Weston's standard pile.

FRANKLIN INSTITUTE

(*Proceedings of the Stated Meeting, held Wednesday, April 19, 1911.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 19, 1911.

Secretary, R. B. OWENS, *Acting Chairman.*

Additions to membership since last report, 6.

The Paper of the evening entitled "Engineering as Related to the Structure of the Body Politic" was presented by Mr. John C. Trautwine, Jr., of Philadelphia, who spoke, in part, as follows:

Without engineering, human co-operation, upon a large scale, is impracticable.

War was probably the first conspicuous instance of such co-operation, and, in warfare, engineering has always been the chief reliance. Indeed, until a little more than a century ago, "the engineer" meant "the military engineer." There was no other.

With the appearance of the steam-engine, practically a century ago, co-operation first became a notable feature of industrial life. The steam-engine brought into being the modern corporation, which is now rapidly bringing all non-governmental industry within its bailiwick.

As a result of this, the community is being (for the most part unconsciously) schooled and trained in the all-important art of organization, and being converted from an unorganized mob into a drilled and correspondingly efficient industrial army.

Concurrently, our governments, city, state and national, are forced, in the protection of the individual against the domination of this growing power, to assert their authority and to assume ever new and stronger powers, at the same time, enormously extending their own industrial activities.

This must result in the eventual assertion, by the people, of their control over all industrial operations, with resulting benefits (to rich and poor alike), with which any private and exclusive individual wealth is as incomparable as it is with that already brought to us by our operation of our public streets, parks, schools, post-office, etc.

After a brief discussion the meeting adjourned.

R. B. OWENS,

Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

*(Abstract from Proceedings of Stated Meeting held Wednesday, April 5,
1911, and the adjourned meeting held Wednesday, April 12, 1911.)*

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 5 and 12, 1911.

DR. GEORGE A. HOADLEY *in the Chair.*

The following reports were presented for final action:

No. 2469.—Crisfield's Moisture Determinator for Coke, etc. Longstreth
award. Adopted.

No. 2476.—Roper Safety Propeller. Longstreth award. Adopted.

No. 2496.—Branch Electric Light Shades. Certificate of Merit. Adopted.

The following reports were presented for first reading:

No. 2458.—Colby Electric Furnace for Melting Metals.

No. 2479.—Behrend High-Speed Electric Generator.

No. 2486.—Jackson's Improvements in the Stability of Dams. Advisory.
Adopted.

No. 2488.—Grover's Clothes Steamer. Advisory. Adopted.

No. 2501.—Wolf Liquid Gas Apparatus and Process.

No. 2502.—Luehr's Improvements in Air Purifying Apparatus. Advisory.
Adopted.   R. B. OWENS,
                                                              Secretary.

FRANKLIN INSTITUTE SCHOOL OF MECHANIC ARTS.

The closing exercises of the School were held on the evening of
Friday, April 21, 1911.

Presiding Officer, James M. Dodge, Vice-President of The Franklin
Institute.

Remarks relating to the work of the School and the Alumni Associa-
tion were made by Mr. Dodge, Director Thorne, and James C. Wobensmith,
President of the Alumni Association.

President Chessman A. Herrick of Girard College delivered an address
to the graduating class, an abstract of which appears in this issue of the
JOURNAL.

REMARKS OF PRESIDENT CHEESMAN A. HERRICK, OF GIRARD COLLEGE, AT THE CONCLUSION OF THE WORK OF THE FRANKLIN INSTI- TUTE SCHOOL OF MECHANIC ARTS.

April 21st, 1911.

President Herrick said in part: "I am pleased to come to these exercises and to bring the greetings of Girard College to the Franklin Institute at the close of its year of school work. In the first place it seems fitting that I should acknowledge the indebtedness of Girard College to this Institution, for it was a distinguished Professor of Architecture of the Franklin Institute—then in the early years of its history—who designed the first group of buildings for Girard College.

By common consent the Main Building of Girard Callege is to-day the purest type of Greek architecture in the world. These original build- ings stand as the finest example of their time of good construction, but more than this, in their imposing grandeur they are ornaments to Phila- delphia, and in addition a protest against the many flimsy, cheap, incongruous and over-wrought buildings now so common. The work of Thomas U. Walter at Girard College and elsewhere in Philadelphia, and particularly in the capitol extensions at Washington, D. C., has placed the whole country under obligation to the Franklin Institute.

I am of those who are without the benefits of specialized scientific or engineering education, but I am not unmindful of the great debt which we all lie under for the discoveries in experimental science, and for the application of science to every-day life, which have been contributed by the Franklin Institute and institutions of its kind; and I trust I shall always be fair enough to give the just dues to the work of these institu- tions in the progress of our times.

The name of Franklin in the 18th century signified much of scientific development during that period, and particularly the utilization of science in order to make life more tolerable. Count Rumford, who had been the moving spirit in the establishment of an earlier institution of the same character as the Franklin Institute in London, stood for much the same tendencies as did Franklin. Franklin had been ridiculed not a litttle in some quarters as the father of the vulgarities of the American people, as the "bread and butter philosopher," etc., but let us not forget that it is from such philosophers as Franklin and the application of scientific discoveries that the world's progress has come about.

We recently buried from Girard College our Chief Engineer, who had been in the service of the Institution for forty years. The service of this man saw the change from oil and gas lighting to the present tungs- ten incandescent burners, and from coal stoves in individual buildings for heat—first, to steam plants located in or near the buildings, and finally to one central heating plant. There have been corresponding changes in the production and distribution of power, until at present there is one

central heat, power, and lighting plant. We have neither noise, dust, worry, nor thought of our power plant, and it is never present to our consciousness except as we have its results, and its results are always satisfactory.

These great changes have come not because of our engineer or because of our contributions—but because of the work done by the Franklin Institute and like institutions, the results of the work of which have been brought to our doors in such form as to enable us to utilize them.

Especially do I congratulate you on the educational work of the Franklin Institute. Upon investigation it appears that your attendance during the year just closing is something like 50 per cent. greater than in the preceding year, and this indicates a tendency which I trust may be marked in the years to come, so that the Franklin Institute will be driven by necessity to the erection of a new and more commodious building in which to carry forward its educational activities.

Your Secretary informs me that these night courses for apprentices, draughtsmen, etc., have been continued for nearly a century, and further that many of the students from these courses have attained to high rank and great usefulness. In these days we hear much of continuation schools, education for the artisan classes, part time schools, and the like, but it would appear that for nearly one hundred years the Franklin Institute has been making a wise and sane contribution to education of this sort, and it may be that when Cincinnati and Pittsburgh, Boston and Pittsfield and a hundred other places over this country shall have adopted from Munich and other German cities the ideals of the continuation school and put them into practice, we shall realize what the Franklin Institute has done for quite a hundred years in the education of apprentices.

I have in the next place a more personal word to those who have been in attendance at the School of Mechanic Arts. It is to almost every man a critical time when he first goes to employment, and every one of experience and observation here present will agree with the statement that the manner in which one spends his leisure hours is a matter of supreme importance. The Patron Saint of this Institution offers a significant example. When Franklin found himself in London he used every opportunity for improvement by attendance upon lectures, discussions, and by the pursuit of all branches of learning. Almost immediately after his return to America and while he was a young man, he originated for the mutual improvement of all its members, the famous Junto Club. Out of this Club there came the Philadelphia Library and the American Philosophical Society, but the spirit of the Junto Club came quite as truly to the Franklin Institute.

In my judgment the Franklin Institute has rendered a most useful and far-reaching service in the opportunities it has afforded for continued education to a large number of young men. The young men of to-day will find greater opportunities for self-improvement than were afforded in Franklin's time, but they will also find many more insidious and alluring temptations than were presented to Franklin to engage in idle and injurious amusement. The motion picture shows, the vaudeville, the dance hall, the

joy ride, and the amusement park are but a few of the attractions by which the youth of the present are lured from the paths of virtue, and the fields of intelligence.

Those who give themselves over to these solicitations will have their intellects stunted, and characters dwarfed. To such the door of large opportunity will be closed. There is nothing which the young man of to-day needs more than continued education after he takes up his life-work. I rejoice that here is afforded opportunity for such education, and also that here are young men who are willing to make the sacrifice in order that these opportunities may be embraced.

The advantages of continued education are two fold: first, in preventing the undermining effect of vapid and evil amusements, and second in the direct service which such education will render. The young man without definite interests and associations in life is likely to fall into the habits of a "sport," and shortly to unfit himself for his regular work, by late hours and the outside associations which he forms. So important is the matter of conduct outside of regular employment that many large concerns are feeling a moral obligation and self interest in the life and activities of their employees.

But the advantages of this continued education are more positive and direct. Persons who fit themselves for large usefulness will not fail to get recognition. As never before the demand is for efficiency,— efficiency of mind, and efficiency of hand. The person who gains for himself by education good judgment, insight, mental balance, point of view, and all that combination of qualities which we recognize in the educated man, cannot fail. The world is asking for men of this sort in every walk of life. They will be quickly singled out from the bleareyed, helpless, dawdling class which think that any preparation and any service is good enough.

In brief, education pays: broad, liberal, fundamental education pays; highly specialized and narrowly technical education pays; education pays in life's satisfactions; education pays in money return. No one has more convincingly set forth the truth of this last statement than has your presiding officer of the evening, Mr. James Mapes Dodge, in a well-known address of his, "The Money Value of Education."

I count myself fortunate in having the opportunity of participating in these exercises, and I take this occasion to say to the Managers of the Franklin Institute that I trust they will continue to stimulate and expand the work of their School of Mechanic Arts: And to you who have been students I can but express the hope that you will continue the good work on which you have entered, and not weary in perfecting and improving yourself for life's duties.

ANNUAL REPORT OF THE DIRECTOR OF THE SCHOOL OF MECHANIC ARTS OF THE FRANKLIN INSTITUTE FOR THE SEASON OF 1910-1911.

The School of Mechanic Arts has given, this season, the most complete series of courses in its history and, although some of its classes have been small and many of the students have not done their proper share of work outside of school hours, the results have been very satisfactory and gratifying, and the Institute should feel encouraged in continuing the expansion of this important part of its work.

This being a night school with nearly all of its students working at their trades and business during the day, it is rather surprising that such technical subjects should interest and hold them as well as is actually the case, and if it were not that they are seriously determined to learn the basic principles and best practices of these arts in order to better their positions, the effort to present them would seem much less hopeful. As it is, the program should be continued so that when the Institute is permanently fixed in a suitable building with proper accessories, it can take a leading position as a night school of technology.

I wish to express my appreciation of the cordial co-operation of my associates and assistants, Messrs. H. E. Hutchins, H. P. Tyson, H. C. Towle, Clement Remington, I. P. Pedrick, John Burt, G. T. Sharp, A. N. McConnell, Frank H. Lobb, and W. W. Twining.

WM. H. THORNE,
Director.

HONORABLE MENTION.

For their interest, industry and success during this season, the following students have received certificates of Honorable Mention:

DEPARTMENT OF DRAWING.

Junior Mechanical Class.

Edwin L. Gibson	George P. Read
George Schick	Harry Letzerch
Malcolm V. D. Remington	George H. Schwarz
Jonathan Tracey	Clarence Gaunt
John H. Frank	Arthur Eyre
G. Frank Brooks	James R. Johnstone
Harry E. Edginton	Warren Russell Snow
Edward Battersby	Elmer W. Coates
Herbert Jayes	

Intermediate Mechanical Class.

Raymond West Betts
Richard Warren
Walter F. Henshaw
M. J. O'Rourke
Fred Gutekunst
Archie F. Murray
Waldemar Rival
Harry Theurer
Leonard Gutekunst

Jeremiah Driscoll
George Schick
Richard Warren, Jr.
M. P. Gregg
Wilbur S. Austin
Ray Sutton
John Tarin, Jr.
John A. McDowell
Robert G. Booth

Senior Mechanical Class.

John T. Dawson
Richard Warren, Jr.

Paul Eichler
Howell J. Floyd
Frederick Rohlfs

Architectural Class.

William S. Bardsley
Raymond C. Harrison
J. Albert Raith
C. Nelson Rocholl

Howard C. Tomlinson
Edgar Worley
William R. Berger
Leon J. Fleischman

Free Hand Class.

H. Walter Stephenson
Theodore A. Nicholson
Leslie M. Holloway

Charles W. Weber
John Zimmerman
John Guarini
Harry E. Donohue

Department of Mathematics.

Algebra.

A. B. Kurtz
Charles Carman
A. C. Chancellor

E. Baumer
Aage Johanson
William Meinel

Geometry.

Charles Crook, Jr.

Walter H. Dardenne
B. B. Roberts

Trigonometry.

Charles Crook, Jr.

Walter H. Dardenne

Department of Mechanics.

Applied Mechanics and Strength of Materials.

Joseph M. Hooper
Warren M. Stone
Robert J. Heiserman

Robert T. Aiman
E. R. Glenn
Albert Ware

Elements of Mechanism and Machine Design.

John Senior
Henry O. Pohrt

Harry Plant
Henry T. Schairer

Structural Design.

Robert J. Heiserman

Robert T. Aiman
Warren M. Stone

Steam Generation: The Steam Engine and Other Prime Movers.

Herbert Ainsworth

Paul G. Binder

Department of Naval Architecture.

Leroy V. Calhoun
J. N. Thompson

S. B. Furstenau
A. Sickler
A. H. MacDade

The following students, having completed a two years' course with satisfactory results, are awarded

CERTIFICATES.

Mechanical Drawing.

William Belfield
Julius M. Netzer
Richard J. Warren
Harry Haman
Howell J. Floyd
John T. Dawson
Pasteur L. Croxton

William Schwindt
Paul Eichler
George Goldsmith
Walter L. Bower
·M. J. O'Rourke
Frank J. Schmieg
Harry Letzerch
Frederick Rohlfs

Architectural Drawing.

Charles M. Carroll
J. Albert Raith

Samuel Lanard Amey
Edward Cogan
Frederick Sponheimer

Mathematics.

Algebra—Geometry—Trigonometry.

Warren M. Stone
Robert T. Aiman
Robert J. Heiserman

Charles Crook, Jr.
Walter H. Dardenne
C. H. Mahler

Department of Mechanics.

Elements of Mechanism and Machine Designs.

John Senior

Henry O. Pohrt
Henry T. Schairer

In the Department of Drawing, Scholarships from the B. H. Bartol Fund have been awarded to the following:

Fall Term.

Edwin L. Gibson	James R. Johnston
John Dawson	William S. Bardsley
G. Frank Brooks	H. Walter Stevenson

· Spring Term.

Fred Gutekunst	Ray Sutton
George Schick	Edgar Worley
Herbert Jayes	Theodore A. Nicholson

SECTIONS.

Mining and Metallurgical Section.—A meeting of the Section was held on Thursday evening, March 23d, at eight o'clock. Mr. James Christie, Temporary Chairman. Forty members and visitors were present.

Mr. George L. Norris, Engineer of Tests of the Vanadium Sales Company of America, presented the communication of the evening on "Vanadium Alloys." The speaker reviewed the history of Vanadium from its discovery by Del Rio in 1801 to the present time. Reference was made to the work of the numerous investigators of this metal including Sir Henry Roscoe, Moissan, Cowper-Cowles, Arnold and others, and the results obtained by them. The characteristics of Vanadium were described as well as its use in alloying with iron, steel, copper, nickel, etc. A number of lantern slides of manufactured products: automobile forgings, piston-rods and locomotive springs, and photomicrographs of sections of steel were shown.

There being no further business the meeting adjourned.

Alfred Rigling,
Acting Secretary.

Section of Physics and Chemistry.—The Stated Meeting of the Section was held in the Hall of the Institute on Thursday, March 30, 1911, at 8 P.M., with Dr. R. B. Owens in the Chair. Fifty-two members and visitors were present. The minutes of the previous meeting were read and approved. Mr. G. B. Heckel, of Philadelphia, publisher of *Drugs, Oils and Paints,* delivered a lecture on "Materials Used in the Manufacture of Paints," in which he described the preparation of each constituent of a paint from the corresponding ore or other raw material. Thus a description was given of the manufacture of white lead by various processes, of the preparation of barytes and whiting from their ores and of the production of zinc oxide from franklinite and of lead sulphate from galenite by metallurgical treat-

ment. The technology of linseed oil, china wood oil, and oil of turpentine was discussed, as was also the manufacture of dryers and of colored pigments.

The address concluded with an explanation of the rôle of each constituent in the mixed paint. The lecture was illustrated by means of lantern slides.

Dr. Goldsmith, Dr. Williams, the Secretary, and others, discussed the paper with Mr. Heckel. A vote of thanks was given Mr. Heckel and, on motion, the meeting adjourned.

JOSEPH H. HEPBURN,
Secretary.

Mechanical and Engineering Section.—A meeting of the Section was held on Thursday evening, April 6th, at eight o'clock. Mr. Thomas Spencer Temporary Chairman. The minutes of the previous meeting were read and approved.

Mr. W. S. Barstow, of New York, then presented an interesting communication on "Small Public Service Properties and Their Future." The paper was devoted to small electric railway, power, gas and electric light plants. The financing and maintenance of such enterprises were given full consideration. Many suggestions on the economical management of such plants were offered interspersed with numerous interesting incidents from the speaker's professional experience.

In the discussion which followed the paper, Dr. Goldsmith and Dr. Owens and the Chairman took part.

A vote of thanks was tendered Mr. Barstow, and his paper was referred to the Committee on Publications. Adjourned.

ALFRED RIGLING,
Acting Secretary.

Section of Photography and Microscopy.—A meeting of the Section was held on Thursday evening, April 13, at eight o'clock. Forty-three members and visitors present. Dr. Leffmann in the Chair. In the absence of the secretary, no minutes were presented. The Chairman reviewed the history of the Section and its work, and referred to the important papers which have been presented at its meeting during the past several seasons. He then exhibited a number of microscopic slides of building materials and lantern photographs of remarkable engineering achievements including numerous bridges and Roman aqueducts. He also described a small four-ampere lamp for photomicrographic illumination, a Nernst lamp and a 100 candle-power incandescent lamp for photographic work, the former two being loaned for exhibition by the Arthur H. Thomas Company of Philadelphia.

Mr. John M. Justice, of Frankford, presented and described a number of lantern views on lightning. He called special attention to the so-called "dark streak" which frequently accompanies a lightning discharge, and exhibited a number of photographic slides which seemed to indicate that it was the reverse image of an ordinary light flash. Adjourned.

ALFRED RIGLING,
Acting Secretary.

Electrical Section.—A meeting of the Section was held on Thursday evening, April 20, 1911, at eight o'clock. Mr. Thomas Spencer in the Chair. Present, eighty members and visitors.

After the reading and approval of the minutes of the previous meeting the Chairman introduced Mr. Carl Hering, of Philadelphia, who presented a communication on the Electric Furnace. He compared the combustion furnace with the electric furnace and described the various resistance and arc furnaces now in use. He presented statistical information as to the size, production, and temperature of the large furnaces of the world, and described the details of their construction by means of many lantern slides.

In the discussion which followed the reading of the paper Mr. G. H. Clamer described in detail the furnace devised by Mr. Hering which was referred to only briefly by the speaker.

Further remarks were made by Drs. Williams, Owens, and several others. Adjourned.

ALFRED RIGLING,
Acting Secretary.

MEMBERSHIP NOTES.

Election to Membership.

RESIDENT.

MR. WALTER HERBERT FULWEILER, care U. G. I. Co., Broad and Arch Streets, Philadelphia.

MR. WILLIAM T. ALLIGER, 5332 Wakefield St., Germantown, Philadelphia.

MR. W. H. JOHNSON, Philadelphia Electric Company, Philadelphia.

NON-RESIDENT.

MR. C. FRANCIS JENKINS, 1808 Park Road, Washington, D. C.

MR. C. J. KIRK, U. S. Sherardizing Co., New Castle, Pa.

ASSOCIATE.

MR. P. T. SHARPLES, West Chester, Pa.

Changes of Address.

MR. FRANK HEPBURN, Trout Creek, R.F.D. No. 3, Jacksonville, Fla.

MR. CHARLES L. REESE, Sixteenth and Brinckle Sts., Wilmington, Del.

DR. SAMUEL C. HOOKER, care of American Sugar Refining Co., S. Fourth and Kent Avenue, Brooklyn, N. Y.

NECROLOGY.

Mr. Craige Lippincott.—Craige Lippincott, president of the well-known firm of publishers, J. B. Lippincott Company, died at his home on April 6th.

Mr. Lippincott was born in this city November 4, 1846, being the son

of Joshua B. Lippincott and Josephine Craige. He was graduated from the University of Pennsylvania in the class of 1866, when he won honors as a student and athlete. On the death of his father in 1886 he succeeded to the presidency of the firm, which had been incorporated the year before. From that time the firm acquired a leading position among important publishers in this country, its products being of a most diversified character including as they do, works of such a widely separated character as fiction and technology, in each of which fields are to be found publications of the highest standard of excellence.

He was a leading figure in the social activities of the city, and was identified with many of the local clubs and societies. Among the latter, the Franklin Institute in the progress of which he displayed an interest both friendly and material.

Colonel Benjamin C. Tilghman.—After an illness of several months Colonel Benjamin Chew Tilghman died at his home in this city.

Colonel Tilghman was born in Philadelphia on March 17, 1861. His father was the inventor of the well-known sand-blast process which was awarded the Cresson Medal by the Institute in 1872. At the age of sixteen Colonel Tilghman entered the scientific course at the University of Pennsylvania and was graduated in 1881. When he had completed his course he entered the business of the manufacture of sand-blast machinery with his father, and upon the death of the latter became head of the company. In addition to his activities in the world of commerce he was also widely known as a student of military affairs, and was regarded by officers of the National Guard of this and other States as one of the most thoroughly versed in military tactics in the volunteer service.

At the time of his death he held the rank of colonel in the Third Regiment of the National Guard. He was a member of a number of social clubs in this city and of the Franklin Institute.

LIBRARY NOTES.

Purchases.

CHATLEY, H.—The Force of the Wind.

MIE, G.—Lehrbuch der Elektrizität und des Magnetismus.

JACKMAN, RUSSELL, CHANUTE.—Flying-Machines: Construction and Operation.

UNDERHILL, C. R.—Solenoids.

BEDELL, F.—Direct and Alternating Current Testing.

COOPER, J. F.—Naval History of the United States. Two vols.

WALKER, J.—Introduction to Physical Chemistry.

CHESNEAU, M. G.—Theoretical Principles of the Methods of Analytical Chemistry.

LANCHESTER, F. W.—Aerial Flight. 2 vols.

JONES, H. C.—Introduction to Physical Chemistry.

THORPE, SIR E.—History of Chemistry. 2 vols.

Philadelphia City Directory for 1911.

Metal Statistics, 1911.

Verein zur Verbreitung naturwissenschaftlicher Kenntnisse in Wien. Schriften, vol. 50, 1909–1910.

Gifts.

Arnold, Bion J. Report on the Pittsburgh Transportation Problem. Pittsburgh, 1911. (From Mr. Bion J. Arnold.)

Belgique Academie Royale des Sciences. Annuaire, 1911. Bruxelles, 1911. (From the Academy.)

New York Academy of Sciences. Annals, vol. 20, pts. 1 and 2. New York, 1910. (From the Academy.)

India Meteorological Office. Rainfall data for 1909. Calcutta, 1910. (From the Office.)

Association Francaise pour L'Advancement des Sciences. Compte rendu de la 38-Session, 1909. Paris, 1910. (From the Association.)

Glasgow, Royal Philosophical Society. Proceedings vol. 41, 1909–10. Glasgow, 1910. (From the Society.)

Ohio Geological Survey. Bulletin 11, Manufacture of Roofing Tiles. Columbus, 1910. (From the State Geologist.)

U. S. Navy Department. Register of the Commissioned and Warrant Officers of the United States Navy and Marine Corps, 1911. Washington, 1911. (From the Department.)

Zi-Ka-Wei Observatoire, Bulletin des Observations. Tome 33, 1907. Fascicule B., Meteorologie. Shanghai, 1910. (From the Observatory.)

Ontario Vegetable Growers' Association. Sixth Annual Report, 1910. Toronto, 1911. (From the Department of Agriculture.)

Venezuela, Ministerio de Obras Publicas Rivista Tecnica, Ano 1, Num. 2. Caracas, 1911. (From the Ministerio.)

American Mathematical Monthly, January to December, 1910. Springfield, no date. (From Mr. John McDowell.)

Interstate Commerce Commission. Twenty-fourth Annual Report for 1910. Washington, D. C., 1911. (From the Commission.)

American Gas Institute, Proceedings, vol. 5, 1910. New York, 1911. (From the Institute.)

Iowa Geological Survey. Annual Report, 1909, vol, 20. Des Moines, 1910. (From the Survey.)

Piano and Organ Purchasers' Guide for 1911. New York, 1911. (From the Music Trades Co.)

Ontario Department of Agriculture, Annual Report of the Bureau of Industries for 1909. Toronto, 1910. (From the Department.)

American Embassies, Legations, and Consulates Mean Better Foreign Business. An Argument in Pictures and Paragraphs. New York, no date. (From the Embassy Association.)

Societe de Physique et D'Historie Naturelle. Compte rendu des Seances, vol. 27, 1910. Geneva, 1910. (From the Society.)

Inventors at Work. George Iles. New York, 1906. (From Mr. George Iles.)

Societe des Ingenieurs Civils de France. Annuaire de 1911. Paris, 1911. (From the Society.)

Philadelphia Bureau of Surveys. Partial Report upon the Comprehensive Plan for the Collection, Purification and Disposal of the Sewage of the Entire City of Philadelphia, 1911. (From the Bureau of Surveys.)

Canada Department of Trade and Commerce Report for year ending March, 1910, part 7. Ottawa, 1911. (From the Department.)

Kansas State Board of Agriculture, 17th Biennial Report for years 1909–1910. Topeka, 1911. (From the State Board.)

Harvard College Observatory. Annals, vols. 65 and 66. Cambridge, 1911. (From the Observatory.)

Rose Polytechnic Institute. Twenty-ninth Annual Catalogue, 1910–1911. Terre Haute. (From the Institute.)

Ontario Department of Agriculture. Annual Report 1909. Vols. 1 and 2. Toronto, 1910. (From the Department.)

Pennsylvania Board of Commissioners of Public Charities, 40th Annual Report, 1909. Harrisburg, 1910. (From the Bureau of Public Charities, Philadelphia.)

Nova Scotia Department of Mines. Report for 1910. Halifax, 1911. (From the Department.)

Railway Statistics of the United States of America for the year 1910. Seventh year. Chicago, 1911. (From Mr. Slason Thompson.)

Locomotive and Carriage Superintendent's Committee. Proceedings during 1910, and at the Lucknow Meeting, December 5, 1910. Bombay, 1911. (From the Secretary.)

India Geological Survey, Memoirs, series 15, vol. 4, fasciculus 3. Calcutta, 1910. (From the Survey.)

Pennsylvania Railroad Company, 64th Annual Report for 1910. Philadelphia, 1911. (From the Company.)

San Fernando Instituto y Observatorio de Marina. Annales, 1909. San Fernando. 1911. (From the Observatory.)

BOOK NOTICE.

College Mathematics Notebook for Classes in Advanced Algebra, Trigonometry, Analytical Geometry and Calculus. Designed and arranged by Robert E. Moritz, Ph.D., Professor of Mathematics in the University of Wisconsin. 106 loose leaves, $10\frac{1}{2} \times 8$ inches, cloth cover. Price, 80 cents. Ginn & Company. Boston, 1911.

When college and university teaching is effective it is necessary for the student to adopt means for recording the subject matter of lectures, etc., for possible future use. To-day in many cases students are being provided not only with information of various kinds by means of lectures,

but they are also being supplied with the latest labor-saving devices by which a minimum of effort is required for recording on paper the information afforded by the lecturer. This notebook constitutes one of the lavor-saving devices referred to. It contains one hundred pages of co-ordinate paper including five pages in polar co-ordinates, the reverse of each sheet being ruled horizontally for other purposes. Also three pages containing important algebraic, geometric, trigonometric and other formulæ. In addition there are three pages containing seven short tables for reference and eight graphs of algebraic and other equations. The notebook cannot fail to serve the purpose apparently intended by the author.

PUBLICATIONS RECEIVED.

North Carolina Geological and Economic Survey. Bulletin No. 22. Cid mining district of Davidson County, North Carolina. By Joseph E. Pogue, Jr., Ph.D. 144 pages, illustrations, plates, maps, 8vo. Raleigh, State Printers, 1910.

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SOME UNEXPLORED FIELDS IN ELECTRICAL ENGINEERING.*

BY

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In discussing the subject of the unexplored fields of electrical engineering, we must consider as belonging to the realm of the electrical engineer, all those phenomena of electricity that are of importance to man: those which are beneficial and useful, and utilized in doing the work of the world, and also those phenomena which are harmful and destructive, and therefore to be guarded against.

It is obviously impossible to touch on all the unexplored fields of electrical energy, for while electrical engineering is not in its infancy any more, nor has been for some time past, there are many more unexplored fields than there are explored fields of electrical engineering; and even in those fields which have been most carefully investigated we find still many unknown regions. A lot of work has been done along many lines since the early days of electrical engineering and a lot of different fields have been uncovered; but there are larger fields still unexplored and there are regions that are still unknown.

To illustrate—there is no simpler and apparently better known phenomenon than the resistance of a conductor. A conductor has a definite resistance which varies with the temperature, etc. With the alternating current the resistance apparently increases in large conductors, because the current flowing in the conductor is not uniform throughout the entire section, but, by the screening effect of the magnetic field inside the conductor, the current density inside of the conductor is less than it is on the outside. We can calculate the phenomena of the lack of uniformity of the current density in the conductor for the case where the current density is not yet very un-uniform, as if in the centre of the conductor the current density is only from 5 to 10 per cent. lower than on its periphery. We get an approximation which is satisfactory for all purposes of electrical engineering, and shows us, how large a conductor we can use without serious waste of conductor material. Then there is the other extreme, where the current density in the middle of the conductor is practically zero, and the current is limited to a thin shell on the outer surface as in the rail return of the single-phase railway, or in ordinary conductors at very high frequencies, as with lightning discharges. This case we can also calculate, determine the current distribution in the conductor, the apparent penetration and the effective resistance of the conductor, with an approximation as close as our knowledge of the constants of the material, the conductivity and permeability, permits. But when you come to the intermediate and probably most interesting case, where there is current even in the centre of the conductor, but a material difference in the current density betwen the outside and the centre of the conductor, we find as solution an infinite series, which in this case converges so slowly as to be practically useless, and this case thus is still practically unexplored.

Another unexplored phenomenon of every-day occurrence: there are many thousands of trolley cars running all over the country with a direct current supply of about 500 volts, and rail return. While the car passes along the track, the current flows from the wheels down into the rails. and then in the rails to the station, as sketched diagrammatically in Fig. 1. At the point A_0 the current enters the rail from the wheel. To the left of this point, it flows towards the left, as indicated by the arrow a. To the right of A_0, it is supposed to flow towards

the right, as indicated by b, and at the point A_0 the current in the rail thus is supposed to reverse. However, the current cannot instantly reverse in the entire rail section, but the same screening effect of the magnetic field in the conductor, which causes unequal current distribution with an alternating current, makes it impossible for the current inside of the conductor to

FIG. 1.
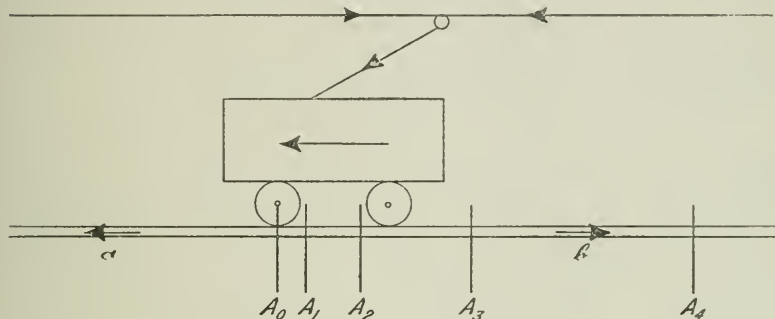
reverse instantly, and in the first moment, the reverse current b thus flows only on the very top surface of the conductor, and only gradually penetrates deeper into the conductor, and before the current flows uniformly throughout the entire rail section in the new direction b, the car has moved hundreds or even thousands of feet. Thus, the current distribution in the rail

FIG. 2.
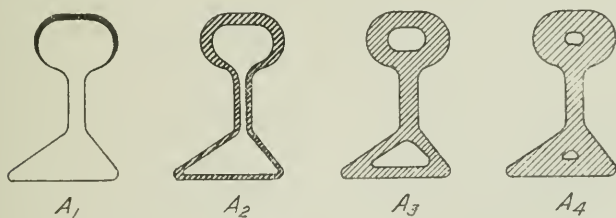
behind the moving car, in the successive sections A_1, A_2 . . . is as indicated approximately in Fig. 2, where the black or shaded portion of the rail shows the section in which the current has already reversed, the unshaded portion the unreversed part, that is, that part, in which the current still flows in opposition to the resultant current flow, is running forwards instead of backwards. The obvious result is an increase of the effective resistance of

the railreturn, which immediately behind a high-speed car may be very considerable. Still this phenomenon, which occurs daily all over the country, has never been investigated, not even been recognized in its existence.

In some fields of electrical engineering or of electrical science we might almost say that we know less now than we knew, or rather believed we knew, a quarter of a century ago. There are things which had been investigated a quarter of a century ago and which were explained in a satisfactory manner to our limited knowledge in the early days, but this explanation does not seem satisfactory now, with our greater knowledge.

A curious example we might cite from the text-books on natural history, for instance. There are supposed to be some fishes which are capable of giving electric shocks. There are some species of gymnotus in the South American mud creeks capable of imparting electric shocks, which have been described a number of times, fishes which have an organ which generates electricity. It has been described as being constituted like a Volta-pile, of a number of successive cells. That theory was quite acceptible twenty-five years ago, but is not satisfactory now. To give a severe shock, would require about 500 to 1000 volts, and it is not intelligible how such voltage could be generated in the conducting animal tissue, without being short circuited. Furthermore, the fish is immersed in water, which is a fair conductor, especially sea water, and 500 volts or more would produce hundreds of amperes in the surrounding water, representing hundreds of kilowatts, and it is not intelligible how such a large power could be generated even momentarily. Thus here we have a mystery, because, after all, the descriptions have been so concise that it is difficult to doubt that there are fishes which can give electric shocks. Just why that phenomena has not been investigated by electrical engineers, we do not know, especially when considering that one of the electric fishes, raja torpedo, lives in the Mediterranean and is frequently caught on the Italian shores, as claimed, thus is within easy reach of engineers.

But we do not need to go so far from home, right at hand we have some of the most important uninvestigated phenomena of electricity. The thunder storm, the lightning, and so forth. In the early days, lightning was explained as the discharge of the clouds. The clouds are positively charged, and the ground

is negatively charged, and the spark jumps from the cloud to the ground. Speculations were made as to how the clouds became charged, and as then the only method of producing electricity was by friction, it was said it might be the friction of the vapor through the air, or the rain drops through the air, or some other form of friction. That explanation used to appear satisfactory, but with our present knowledge of dielectric phenomena, it is not satisfactory any more.

It was thought that lightning was the discharge from the cloud to the ground. That means that the electric field between the cloud and the ground must be beyond the breakdown strength of air. In a uniform field, the breakdown strength of air is about 75,000 volts per inch, or nearly a million volts per foot. Even if the cloud is only 1000 feet above ground, this would require a thousand million volts. If there were an electrostatic field between the cloud and the ground of a thousand million volts extending over the whole area of the thunder cloud, this would represent such an immense amount of electric energy, that it is inconceivable how any reasonable source of energy can produce it; how it can exist without having a destructive effect far beyond anything known of lightning. Furthermore, a uniform field cannot well exist between clouds and ground, on account of the unevenness of the ground surface.

Let us look into another conception, not a uniform electrostatic field, but an un-uniform field, like that of the discharge between points. With long striking distances between points, the average gradient is about 170,000 volts per foot. This would require only 170 million volts between a cloud 1000 feet high, and the ground. This would be more reasonable. It would not require such an unreasonably vast amount of stored electric energy. But we know that in such an un-uniform field the spark is preceded by a brush discharge covering more than half the distance. Thus, lightning should be preceded by a brush reaching down from the cloud and up from the ground, for several hundred feet. Now such an enormous brush has never been observed, and is inconceivable: the brush discharges occasionally observed at points during storms are only a few inches long. Furthermore a 300-foot brush is inconceivable, because the resistance of the ground is not low enough to conduct the energy necessary to maintain such a brush discharge.

Furthermore, most of the lightning discharges are not between the cloud and the ground, but are internally in the clouds, frequently reaching the length of several miles. So you see the explanation of the lightning as a spark discharge similar to the discharge of the friction machine appeared plausible in the early days, but with our present knowledge it is not tenable any more.

We cannot consider the lightning discharge as a simple electric rupture, in the same way that an overloaded beam may break mechanically, but as an equalization of internal stresses, about as a piece of hot glass that is rapidly chilled, and thereby full of internal compression and tension strains may suddenly break all over, by the internal stresses. So with our present knowledge, we must consider as the most probable explanation —although not certain by any means—that the lightning discharge is the phenomenon of the equalization of internal electric stresses in the cloud, and is analogous to the splintering or breaking of an unevenly stressed brittle material, like glass.

The question then is, how do those uneven electrostatic stresses originate in the cloud, and how do they reach such values as to cause internal equalization by rupture? If there has been produced a very highly unequal distribution of voltage in the electrostatic field of the cloud, it is easy to see how a discharge can pass along miles of cloud, without such unreasonably great potential differences as would be required for a direct discharge across space, just as from a scratch in a poorly annealed glass plate cracks may run all over the plate, splintering it in all directions. Assuming that the potential distribution in the cloud becomes very uneven. If then at some point the potential gradient becomes higher than the disruptive strength of air, at this point a local disruptive discharge occurs, perhaps only a few inches in length. This discharge equalizes the potential gradient within its path, and thereby increases the gradient at the ends of the discharge. If this gradient is already fairly high, it rises beyond the disruptive strength of air, and thereby the discharge extends farther along the discharge path, but by the voltage equalization resulting therefrom, still further increases the potential gradient ahead of the discharge, and in this manner the equalizing discharge extends farther and farther, possibly for miles, side discharges issue from it or run into it,

until finally cloud regions are reached, where the initial potential gradient is very low, and the discharge gradually tapers down.

But where does the initial voltage come from, and how does it become uneven?

It is not so difficult at least to make a preliminary estimate of the building up to very high, and uneven voltage distribution in the cloud, as soon as you have assumed some initial voltage. We do not know where the initial voltage comes from, but we must accept the fact that there is normally a voltage gradient in the air, a potential difference between different altitudes which may amount to a hundred volts or more per foot. In the air 100 feet above the ground, there may be a potential difference against ground amounting to thousands of volts. If you bring a wire up to there you do not carry a current down, but you merely carry the ground potential up, but by a carefully insulated electrostatic voltmeter you can measure these potential differences. Possibly, this potential gradient in the atmosphere may even be of cosmic origin: the earth having a high negative potential against our solar system, against the universe, which would mean that there must be a positive voltage gradient from the surface of the ground into space.

If condensation takes place in the higher regions of the atmosphere, rain-drops form, minute drops at first, which necessarily must be at the potential of the air in which they form. That means they have a potential difference against the ground, and therefore an electrostatic charge against the ground corresponding to this potential difference. Assuming now that many of these minute rain-drops conglomerate to larger drops, it means, that many small condensers conglomerate to one condenser, which is somewhat larger in capacity, than each component, but very much smaller in capacity than the sum of the capacities of its components. But it contains all the electrostatic charges of the rain-drops, and at the much smaller capacity, the same charge gives a higher potential difference: Suppose a thousand small rain-drops conglomerate into one large one. This has ten times the capacity but 1000 times the charge, hence a hundred times the voltage. Conglomeration of minute drops into larger ones thus must give a great increase of potential difference against ground.

We know the clouds are not uniform in density, and where

the density is greatest conglomeration of condensed drops takes place to a much greater extent, building up to a much higher voltage, and thereby between the parts of the cloud of different density, the light and the dark portions, potential differences must appear and increase with increasing condensation, until somewhere the disruptive gradient is passed, equalization occurs by a lightning discharge, and then the same play repeats again and again.

Lightning discharges then are the result of the voltage unequalities produced in the clouds by the unequal rate of con- glomeration of rain particles due to the unequal cloud density.

In agreement with this is, that heavy lightning strokes are usually followed by a heavy down-pour of rain: in reality they are preceded and caused by it, but it takes time for the rain- drops to come down.

Let us assume now that the process is reversed, and after conglomerating to high voltages the rain-drops evaporate again. Since gases apparently do not carry electrostatic charges, the rapidly dwindling rain-drop retains its entire charge, hence must rise in potential, and finally must discharge, and this pro- gressive evaporation of the rain-drops must also result in the building up of potential differences and therefore the formation of lightning, and this may explain the two forms of lightning, that accompanying rain-storms and thunder-storms, and the so-called " heat " lightning.

The former is the result of condensation and conglomeration, the latter the result of evaporation of rain-drops.

You see then, that in this field, which is not merely of theoretical interest, but of high industrial and general impor- tance, our knowledge is still very limited, it is a fairly unexplored field of electrical engineering and electrical science. It is a branch of electrostatics, of the phenomena of the dielectric field. The phenomena of the dielectric field we cannot very well call unexplored, because there has been a great deal of investigation in the early days, and volumes have been written on it. Many of us may still remember the early days when the text-books of electrical engineering started with the theory of the distribu- tion of the electric charge, investigated the electric density on an ellipsoid and all that sort of thing. All this has now pretty well vanished from electrical engineering text-books. With the development of electrical engineering, electrostatics became of

less interest and were thus neglected. Only in recent years, when we have in transformers and transmission lines reached voltages higher than in almost any electrostatic machine, and those not of a negligible power, but of a very large power, the field of electrostatics has become a very important one, and has to be studied again.

We now find that in the study of electrostatics, the conceptions of the work of former days is untenable, from our present point of view; we cannot conceive of the dielectric phenomena as a charge on the conductor surface, we know there is not an electric charge on the conductor, the dielectric energy resides not on the conductor surface, but is in the space around the conductor, in a dielectric field, and the so-called " charge " is nothing but the termination at the conductor surface, of the electrostatic field in space. It is the electrostatic or dielectric field, which we must consider as representing the phenomena of electrostatics, in the same way as Farady has shown us with the magnetic field.

The old conception of the electrostatic charge on the conductor has been the cause of the far greater difficulty which we find in dealing with even simple phenomena of electrostatics, compared with the simplicity, with which even apparently complex phenomena are treated by the conception of the lines of magnetic force.

We must then abandon the conception of the theory of electrostatics of the early days—which still largely is used in theoretical text-books—as incorrect and useless. Capacity then is not the capability of the conductor to store electric quantity, but is the ratio of the number of lines of dielectric force, to the electromotive force which produces them, just as permeance is the ratio of the number of lines of magnetic force, to the magnetomotive force which produces them, the " charging current " is no more a current charging the conductor with electricity, than the " inductance voltage " is a voltage charging the conductor with magnetism; the former, as " capacity current " supplies the energy stored in the dielectric field, just as the inductance voltage supplies the energy stored in the magnetic field, and dielectric and magnetic phenomena are very largely analogous and treated in the same manner, and with the same simplicity.

This was not possible with the conception of electrostatic

charges, and even simple problems, as the calculation of the capacity and the mutual capacity of parallel conductors, become so complicated that the most satisfactory method of their calculation was not to calculate the capacity at all, but calculate the corresponding inductance, and derive the capacity by the relation, that capacity times inductance equals the square of the velocity of propagation, which in space is the velocity of light (3×10^{10}).

You see then, that in this field, which is of the highest industrial importance now, where we have in transmission lines reached voltages which approach those of lightning, we are only just in the beginning of an intelligent understanding, an insight into the phenomena.

Now we come to another field, not very far distant from the previous one: *Conduction of gases and vapors.* It is a field in which an enormous amount of investigation has been carried on in the last years by the physicists, so that it may almost be called the best explored branch of modern physics. Unfortunately, there has been very little, if any, benefit from all this work, to the electrical engineer. If you ask some simple engineering question, as for instance, you have a Geissler tube, 4 cm. diameter and 10 m. long, filled with nitrogen gas under 0.1 mm. pressure. What will be the voltage required to pass a current through the tube, what will be the amount of light given by it, and how will the voltage vary with the current and with the gas pressure? The answer is unknown, in spite of the enormous amount of scientific work done in gas conduction, nothing is known even of the most elementary electrical questions, the relations between voltage and current, dimension and gas pressure.

We have a great mass of physical studies on gas conduction, but naturally the engineer cannot have much confidence in these scientific investigations on " how " and " why " and " wherefore " of the phenomena, if the question " what are the phenomena " remains unanswered, is apparently overlooked.

We now have some data on the electrical constants of gas conduction, and our knowledge is rapidly increasing by the work of the engineers, who finally, as in other fields of research, have despaired of ever getting the scientific investigators to drop metaphysical speculations long enough to determine physical facts, have started to investigate the engineering facts themselves.

The same applies to arc conduction, though arc conduction has been investigated by the engineers for a much longer time, and more is known about it.

In the arc, the voltage required to maintain an arc of constant length, decreases with increase of current. This voltage consists of two parts, one, which is constant and independent of current and arc length, the " terminal drop," and one, which decreases with increase of current and thus of arc stream section,

FIG. 3.
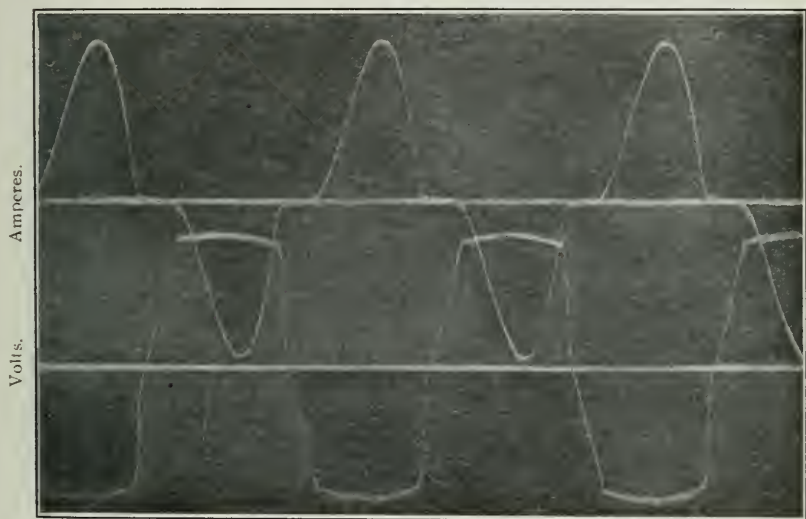
Oscillogram of Geissler tube, 0.1 amp., 3000 volts : upper curve, current ; lower curve, voltage.

and increases with the arc length, and is of the nature of a voltage consumed by a resistance, the " stream voltage."

In the Geissler tube we also have a terminal drop and a stream voltage, but their proportions, and their variation seem to be very different from those in the arc. The terminal drop decreases, and the stream voltage increases with increase of gas pressure, so that the sum of both, or the total voltage consumed by the Geissler tube, is a minimum at some intermediate gas pressure—which minimum voltage gas pressure depends on the proportion of terminal drop and stream voltage, and thereby on the length of the tube.

However, the terminal drop seems not to be independent of the current, but to increase with increase of current, while the stream voltage—which is proportional to the length of the stream —seems to be practically independent of the current within a wide range. The voltage wave of an alternating Geissler tube discharge thus is characteristic, but entirely different from the characteristic voltage wave of the alternating arc. The former is shown in Fig. 3, the latter in Fig. 4.

Much of the work done on arc conduction is worse than useless, by unjustified generalization. Too often investigators have taken a pair of carbon terminals—since carbon terminals

FIG. 4.
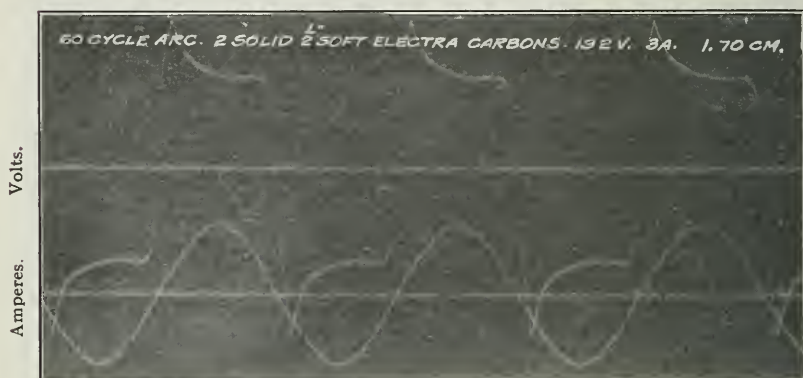
Oscillations of carbon arc : upper curve, voltage ; lower curve, current.

are mostly used in arc lamps—have put various things on them, and then written a treatise on " the arc," without ever realizing, that whatever applies to the carbon arc, does not necessarily apply to any other arc.

The conductor in the Geissler tube is the gas which fills the space between the electrodes, and the material of the latter therefore of secondary importance, but the phenomena, as the voltage, the color and the spectrum of the light etc., essentially depending on the nature of the gas in the space between the electrodes, and on its pressure. In the arc, however, the conductor is a stream of electrode vapor, the material of the electrode therefore of fundamental importance on the voltage, luminosity, color and spectrum of the arc stream, while the

surrounding gas is of secondary importance only. The conducting vapor stream, or " arc stream," usually is at the boiling point of the electrode material. The carbon arc thus is the hottest arc. The dielectric strength of gases decreases with increase of temperature, and at the temperature of the carbon-arc stream has fallen below the voltage drop in the arc stream, so that in the carbon arc all the phenomena resulting from the dielectric strength of the vapor stream are absent, since the surrounding air has a disruptive strength less than the supply voltage of the arc. Nearly the same is the case with a few other very hot arcs. The carbon arc thus is not a typical arc, but is one of the extremes in a series of arc conductors, of which the other

Fig. 5.
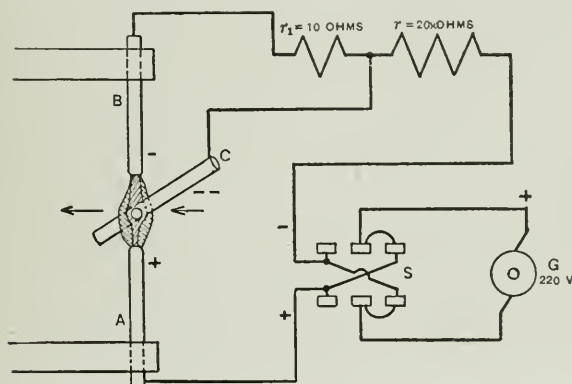
extreme probably is the mercury arc, as the coldest arc. The latter thus gives the phenomena of the dielectric strength of the arc stream most pronounced.

In a general investigation of a class of phenomena, the first problem is to select reasonably typical conditions, and afterwards extend the study to the extremes. In the study of arc conduction, the use of the carbon arc as typical arc thus is no more justified, as it would be in the study of the phenomena of the melting point and the boiling point to select carbon as typical material.

This appears obvious, but very frequently has not been realized.

As the phenomena of arc conduction essentially depend on

the temperature of the arc stream, that is, the boiling point of the electrode. material, typical conditions we can expect only from electrode materials having boiling points intermediate between the extremes, carbon and mercury. Such are many metals, as iron, copper, etc. The iron arc thus is a typical arc, but not so the carbon arc.

In the study of a typical arc, we find that the vapor stream, which conducts the current, issues from the negative terminal, as shown by its spectrum, and by the character of the arc: the latter depends on the material of the negative terminal, but is unaffected by any change of the positive terminal. The vapor conductor of the arc is moving rapidly from the negative terminal towards the positive, and is a conductor in the direction from the negative terminal to any point reached by the arc stream, which is positive towards the negative arc terminal, but is non-conducting with regard to any body negative towards the negative arc terminal. Thus, if I draw an arc between two iron or copper terminals A and B, with A as positive and B as negative terminal, and approach the arc with a third terminal C, which is connected to the positive side A of the circuit, as soon as I touch the arc flame, the arc leaves the terminal A and goes over to the terminal C. If, however, the terminal C is negative, as in Fig. 5, even much more negative than the negative arc terminal B, I may immerse the terminal C into the arc stream, for instance, by passing it through the stream from one side to the other, as indicated by the arrows in Fig. 5, but the arc stream does not leave the negative terminal B and goes to the more negative terminal C, that is, the arc stream is non-conducting towards negative C, but is conducting towards positive C. That is, the arc stream is a unidirectional conductor, and therefore can be used, and is extensively used for rectification.

In the experiment illustrated by Fig. 5, if I raise the voltage between C as negative and A as positive sufficiently high, that is, beyond the disruptive strength of the gap from C to A, the arc will be started from C to A by a disruptive spark.

The voltage range, within which an arc stream is non-conducting towards a negative body, or, as usually called, the " rectifying voltage range of the arc stream," is determined by the disruptive strength, and thus is a function of the temperature. Hence, it is many thousand volts with the low temperature mer-

cury arc, is still several hundred volts with the iron or copper arc, but vanishes below the temperature of the carbon arc, and the latter thus does not show any more the unidirectional conductivity of the arc stream to any marked extent, thus is an exception, and not a typical arc.

As in arc conduction the conductor is the unidirectionally moving electrode vapor stream, this vapor stream has first to be produced, by the expenditure of energy, before arc conduction can begin. Thus an arc has to be " started " by some of the various ways of producing the arc conductor, as by bringing the terminals into contact, or by passing an electrostatic spark between the terminals, etc. For the same reason, in an alternating current arc at every half wave a new arc stream has to be started, in opposite direction from that of the preceding half wave of current, and the supply voltage thus must be high enough to jump a static spark across the arc terminals through the residual hot vapor of the preceding half wave. This voltage is low with the carbon arc, but becomes very high with lower temperature arc. Even in the carbon arc, however, Fig. 4, the starting voltage peak is shown at the beginning of each half wave.

Entirely different from arc conduction apparently is the conduction of the Geissler tube and of the electrostatic spark. Geissler tube conducton and electrostatic spark, however, apparently are the same phenomenon, differing only by the difference of gas pressure. It appears startling to think, that the brilliant, noisy static spark, and the noiseless diffused Geissler tube glow are the same phenomenon. However, by gradually changing the gas pressure, the one gradually changes into the other.

The electrostatic spark, as produced in air under atmospheric pressure, passes between the terminals in an irregular shape, as a sharply defined thin zigzag curve of very high brilliancy and with a loud noise. If now we gradually lower the air pressure in the space in which the spark takes place, we find the spark gets less and less noisy and less brilliant, becomes thicker in diameter, less sharply defined, straighter; then the noise vanishes altogether, the spark thickens out still further, the brilliancy continues to decrease, its outside becomes more fluffy and finally surrounded by a kind of a penumbra, and finally the discharge uniformly fills the entire space as a uniform steady glow

of low brilliancy, which frequently shows the typical striations of the Geissler tube. Increasing air pressure again gradually changes the phenomenon from the steady noiseless Geissler tube glow of low brilliancy to the noisy thin spark of high brilliancy. Increasing the pressure still higher, above atmospheric, the spark becomes still more noisy and thinner, and more brilliant.

Thus the difference between the usual static spark and the Geissler tube glow is one of degree only, but not of quality. However, even this is largely due to extraneous conditions.

When speaking of the electrostatic spark, we usually think of the short-circuiting spark, that is, the spark which, when passing between the terminals, closes the circuit of the voltage supply, and thereby is accompanied by a big current rush, which gives the brilliancy and the noise. If, however, the spark does not short-circuit the voltage, but the current is limited, as for instance by a very high resistance, or by the interposition of a dielectric in the discharge path, which does not puncture, as a glass plate, the apparent difference between Geissler tube glow and static spark is much less. Thus if we have a spark discharge between two terminals, with a glass plate interposed to keep the discharge from short-circuiting, with a considerable distance between the terminals, and correspondingly high voltage, we get static sparks jumping from the terminals to the glass plate, which are of the same character as the typical short-circuiting spark, but less brilliant and less noisy. Decreasing now the distance between the terminals, and the voltage, the sparks become more numerous, but still fainter and less noisy, and gradually change to so-called "steamers," which pass with a hissing noise in sharply defined faint lines, and finally, when still further shortening the gap, the noise disappears, and the discharge changes into a uniform and noiseless faint glow, very similar to that of the Geissler tube.

Thus we can pass gradually from the noisy and brilliant short-circuiting spark to the streamer, brush discharge, corona and to the silent discharge or steady glow.

But while a gradual transition from Geissler tube conduction to spark conduction exists, I have never been able to get any gradual transition from Geissler tube conduction to arc conduction, but under conditions where both can occur, the one always changes abruptly into the other, and these two classes of

conduction thus seem to be different in their nature: the one con-
duction by the gas in the space between the electrodes, the other
conduction by a stream of electrode vapor. Both can be pro-
duced in the same tube, as a mercury arc and a striated Geissler
tube discharge through mercury vapor, but the one cannot be
changed into the other gradually, but the change always is abrupt.
For instance, if we have a Geissler discharge through mercury
vapor, of limited current and high voltage, and gradually cut the
resistance or reactance out of the circuit, or increase the supply
voltage, the Geissler discharge suddenly, with a " flash " changes
to arc conduction; the current rises and the voltage drops.
Cutting resistance in again, just as sudden the arc drops, and is
superseded by the Geissler discharge.

Here then we have a very interesting and very important
field, in the conduction of gases and vapors, in which still very
much is unknown.

Magnetism has been the phenomenon of the greatest impor-
tance to the electrical engineer since the earliest days, since all
electrodynamic machinery is based on the use of the magnetic
field. Nevertheless, even in this field we have in " permanent
magnetism " a phenomenon which is still unexplained, and mys-
terious. Permanent " magnetism " was a satisfactory expression
once, but is not now, as " magnetism," " electricity," etc., are
general terms now, without any definite and well defined mean-
ing. So the question is, what is permanent in the permanent
magnet? The magnetic flux, or the magnetomotive force, or
the flux density or flux distribution, or the magnetic energy?

Another interesting and important phenomenon of magnetism
is the loss of energy by a cyclic change of magnetism, as occurs
in an alternating magnetic field. Twenty years ago. I found this
loss to be expressed empirically by the 1.6th power of the mag-
netic flux density, with sufficient approximation over a wide
range of magnetic densities. Since that time, some observers
have found that for very high magnetic densities the loss is less
than that given by this law of the 1.6th, and other observers
found that it is more. Considering the great difficulty of getting
exact results at high densities, it appears probable herefrom
that even at high densities the law of the 1.6th power still
applies at least approximately. For very low densities I have
shown that it finally cannot continue to hold, but the coefficient

must increase to 2.0. However, with all the work done on magnetism, we still are entirely in the dark regarding the cause of this strange coefficient 1.6. The only other instance of such a fractional exponent is the exponent of the adiabatic expansion curve of gases, 1.4, etc.

Only recently another instance has been found, where the coefficient 1.6 appears.

The resistance of pure metals, as the tungsten filament, is proportional to the absolute temperature:

$$r = aT$$

The black-body radiation, however, is proportional to the 4th power of the absolute temperature, and if no other loss of power occurs, as when the radiator is enclosed in a high vacuum, as in the tungsten filament incandescent lamp, the power input equals the radiation power, and thus also is proportional to the 4th power of the absolute temperature:

$$p = bT^4$$

substituting:

$$r = \frac{e}{i} \text{ and } p = ei, \text{ gives:}$$

$$\frac{e}{i} = aT$$

$$ei = bT^4$$

eliminating T, gives:

$$e^3 = \frac{b}{a^4} i^5$$

or:

$$e = c i^{1.6}$$

That is, in a perfect metal, which gives black-body radiation, in a high vacuum at higher temperature the impressed voltage varies with the 1.6th power of the current.

This is the only other instance of a 1.6th power law, which I found. It may be a mere coincidence, but it is interesting to reflect, that here as well as in the hysteresis law, a conversion of electric energy into heat takes place.

It is not possible to discuss all the unexplored fields of electrical engineering, or all the vast regions of otherwise well explored fields, where very little is known: but even in fields where very much is known, there are numerous trails leading

into unexplored regions, which never have been explored. Magnetism, for instance, is one of the most explored branches of electrical science. It was known many years ago, that manganese has some curious magnetic properties: a few per cent. added to iron makes it practically non-magnetic. However, it is non-magnetic only in its virgin state, and by heat treatment it is brought into a magnetic state, where it has about the same characteristics as other steels. Here then you find a material which may be magnetic or unmagnetic. This trail was never followed up until a few years ago, when a strongly magnetic alloy of manganese, copper and aluminum was discovered. It seemed to overthrow all our conceptions on the nature of magnetism as an elementary property. Even then, however, most investigators followed the same trail, making various alloys of these three metals, and speculating on the cause of the magnetic property of the alloy of three unmagnetic metals, without following the trail further, to the study of other alloys of these metals. Such study shows, that copper and aluminum are immaterial for the magnetic property, but that manganese is essential, and is indeed a magnetic metal. Pure manganese has never been produced in the magnetic state, but numerous alloys of manganese, as those with antimony, tin, zinc, etc., are magnetic or may be brought to a magnetic state. Most interesting is the manganese-antimony alloy, as it can be produced much easier than the Heussler alloy of manganese, copper and aluminum: mixing coarsely powdered manganese and antimony, in the proportion for instance of $1 : 3$, by moderate heating—in a test-tube over the bunsen burner—the mass becomes strongly magnetic, and can be used to show the lines of force of a magnet, just like iron filings. When I tried the magnetic properties of a collection of various alloys, which I had since a considerable number of years, I found quite a number of manganese alloys, which showed magnetic properties. Thus after all we do not have to change our conception of magnetizibility as a property of the element, but it merely means, that manganese—and possibly chromium—have to be added to the list of magnetic metals.

Oxygen also is magnetic, and now should be easily available, but I do not know that its magnetic characteristics have ever been investigated, except very roughly and qualitatively. While

it may not be of industrial importance, it certainly is of great scientific interest, as the only magnetic non-metal and non-conductor. We do not know its magnetization curve, whether magnetic saturation occurs, and what the saturation value is, whether there is a hysteresis loss, etc., whether and how far ozone shows the magnetic properties, etc.

There is in the literature since many years a curious oxide of chromium mentioned, which has strongly magnetic properties. It is formed by the reduction of chromylchlorid, within narrow temperature limits.

With manganese, a lower oxide of the metal seems to exist, which has much greater magnetic properties than any of the manganese alloys investigated, and even on the old and well-known magnetic oxide of iron, the only data which we have are investigations made twenty years ago, but which apparently have never been continued further.

You see, there is really no lack of unexplored phenomena in the realm of electrical science and engineering, far more than can be touched upon in the short available time. But the two vast fields, in which an increased knowledge is of immediate industrial importance, and in which indeed energetic investigating work is going on, are the study of the properties of materials beyond the elastic limit, and the study of transient phenomena resulting from the readjustment of the stored energy of systems.

Most investigations of physicists have dealt with the properties of materials below the elastic limit, where the processes are reversible. But of almost greater interest is the range beyond the elastic limit, where the action of forces is not reversible, where mechanically the materials are deformed, flow, where the steel is rolled into rails, the wire is drawn. So with the electrical forces, in the electrostatic field, irreversible phenomena occur at high voltage, in the corona: energy is stored into the dielectric field, but is not returned, but dissipated as heat, if the dielectric flux density reaches beyond the disruptive strength of the material, and in our modern high voltage transmission lines we have closely approached this limit. In the field of magnetism, the phenomena of hysteresis represent such an irreversible process. So also the ageing of many kinds of magnetic materials, etc.

The second important field of investigation is the study of the transients. Transients are the phenomena, by which stored energy adjusts itself to changed conditions of the system. Most of our electrical engineering theory deals with the steady flow of electric power, by direct or by alternating current. But accompanying the flow of electric power is a storage of electric energy in the magnetic and in the dielectric field of the conductor, and any change of the circuit conditions, any change of current and of voltage, thus usually involves a change of the stored magnetic and dielectric energy. Since a change of stored energy cannot occur instantly—as this would represent infinite power—a transition period thus must intervene after every change of circuit condition, that is, an electrical transient occurs. When the electric systems were small, these transients usually were of negligible energy; but with our modern huge systems, the stored energy is such, that the transients frequently may reach destructive powers, and therefore their study has become of great industrial importance.

DISCUSSION OF DR. STEINMETZ'S PAPER.

Mr. W. C. L. Eglin: I am sure we are all very much indebted to Dr. Steinmetz, and I am sure he will be very glad to have any discussion that his remarks may have suggested.

Mr. H. C. Snook: I would like to ask whether Dr. Steinmetz thinks there is enough data at present to formulate any satisfactory theory of what electricity really is?

Dr. Steinmetz: While we still speak of electricity, or of magnetism, these terms have really ceased to have a definite meaning of some concrete thing or phenomenon, but rather mean an entire class of energy phenomena. With our increasing knowledge, instead of speaking broadly—and vaguely—of electricity, we discuss electric power, electric energy, electric current, voltage, quantity, etc., so that it may be said, that there is no such thing as electricity, but there is electric energy, electric power, etc., and the term electricity is applied largely to an entire class of phenomena. We may ask, "What is electric energy?" and then would answer, that it is a form of energy, which can be transmitted through a conductor, around which conditions of magnetic and dielectric stress are produced.

Mr. Snook: Yes, but there are two kinds of electricity, or two kinds of energy.

Dr. Steinmetz: Some speculative physicists have developed a conception of two forms of electric quantity, negative and positive. Others have denied the existence of positive and recognize only an excess or a deficiency of negative electric quantity. However, in reality, there is no absolute nega-

tive or positive, but it is entirely relative. That is, a point which is positive against another point, may be negative against a third point. For instance, the negative terminal of the mercury arc rectifier is the positive terminal of the rectified circuit fed by it.

Question: I would like to ask Dr. Steinmetz what are the elementary properties in a thing, or phenomenon, that make it electrical?

Dr. Steinmetz: I would define a phenomenon as electrical, if it is accompanied by magnetic or electrostatic fields.

Question: The difficulty with that answer is, that the word "electrostatic" is used for the properties which constitute the phenomena in the electrical field.

Dr. Steinmetz: You might define the electrostatic or dielectric field as a condition of stress in space, which exerts mechanical forces on light bodies, and which is polarized, that is, the forces may be in one, or in the opposite direction, positive or negative.

Question: Since the discovery of radium, they have formulated an electronic theory of mineral matter; that is, the influences are supposed to be the same thing that passes through the Geissler tube. Now if matter is composed of electrons, and matter is a flow of electrons, where do we stand?

Dr. Steinmetz: This conception attempts to begin, where we engineers end, that is, to explain how and why the phenomena occur. As engineers we are interested only in the facts, that is, determine how things occur. For instance: that in the arc, a stream of moving electrode vapor is the conductor. The metaphysician then speculates, why this moving vapor stream conducts, whether electrons carry electric quantities across the gap, and what these electrons are, etc. For us, this is of secondary interest only, and rather dangerous, since it is largely speculative, and you cannot safely design apparatus or build bridges with speculations, but you must have engineering facts.

Dr. Hoadley: There is one thing that has always had a certain amount of interest for me, and that is this: Suppose we have two insulated conductors, charged to a different potential with negative charges; and suppose we have two other conductors with positive charges; suppose that the two negative conductors are permitted to come in, and the two positive conductors are permitted to go together; what is the direction of the charge which reduces them to the same potential in each case?

Dr. Steinmetz: I think your premises are wrong. You speak of two conductors charged to different potentials with negative charges. But there is no negative charge, but negative is a relative expression only, and means negative with regard to another conductor as reference point, for instance, to the ground. Thus if you speak of two conductors of different negative potentials, it must be stated, with regard to what third conductor they are negative. They may be negative for instance with regard to the ground, and the two positive conductors positive with regard to the ground. But then that conductor, which is least negative with regards to the ground, is positive with regard to the conductor which is more negative towards the

ground, and the conductor, which is less positive towards the ground, will be negative towards the conductor, which is more positive towards the ground. But with regard to each other, of each pair of conductors, one is negative with regards to the other, and the other positive with regard to the former. You may, for instance, consider an insulated circuit, energized by a direct current source. One of its terminals is positive, the other negative, with regard to the other. If now you connect the circuit to the positive terminal of a high voltage source, of which you ground the other terminal, the entire circuit will be positive towards the ground, but still the one circuit terminal is negative regarding to the other, and the current flows in the circuit exactly as before.

That is, positive and negative are relative terms only, but not absolute, in their electrical engineering meaning.

Question: Mr. Chairman: The theory of thunder-storms production would seem to indicate that it is advisable to use ordinary lightning rods for the protection of buildings and high exposed points of structures. Is that correct?

Dr. Steinmetz: It is, undoubtedly. The lightning rod is a great protection, and I would not like to be in an exposed place without such protection. But you must not expect that one rod on one end of the building will completely protect the other end a hundred or more feet away. There must be sufficient rods to extend their protective zone over the entire area; the apex of the roof, and other projecting edges, must be protected by connecting wires, etc. That is, like any other apparatus, the lightning rod protection must be installed intelligently and properly, to be effective. But the general principle is correct, only, it must be rationally applied.

Nitrates in the Atmosphere of the Southern Regions. A. Müntz and E. Lainé. (*Compt. rend.,* clii, 166.)—The first step was to determine the quantity of nitrates and nitrites in the rain water of these regions for comparison with the quantity in the water of other parts of the earth. The production of these nitrous compounds in the atmosphere was found to be due to the frequent electric storms of the inter-tropical regions; which is corroborated by the fact that these nitrous compounds are not found at high altitudes, in the zone above that in which the storms are produced. The quantity of nitric acid varied from 1 to 4 m.g. per litre of water, while the highest figure for Alsace 0.43 m.g. and for England 0.42 m.g. At Caracas, the mean content was 2.23 m.g.

Wireless Telegraphy in an Aeroplane. A. Senougue. (*Compt. rend.,* clii, 186.)—Maurice Farman using a coil with a 10 cm. spark and fed by the current of four accumulators, sent clearly perceptible signals for a distance of 12 kilometres. One pole was connected by steel wires to the metallic body of the aeroplane, while the other pole was connected to carefully isolated

antennæ, consisting of two copper wires, 50 M. long and 0.4 m.m. diameter, hanging parallel to each other behind the apparatus. During the flight these wires attained an almost horizontal position. The total weight of the apparatus was about 20 k.g. Farman did not carry a passenger, but was his own operator. The waves were received by a Ferrié electrolytic detector, connected to horizontal antennæ 200 M. long carried on posts 8 M. high.

Heat Conductivity of Powdered Substances. M. SMOLU-CHOWSKI. (*Anz. Akad. Wiss.*, Series A. 129.)—The heat conductivity of the following substances was determined experimentally, quartz sand, zinc dust, iron powder, zinc powder, rice flour, lycopodium seeds, cupic oxide, lampblack and kieselguhr, with special attention to the nature and pressure of the gases filling the interstices between the grains of the powders. The results showed that the heat conductivity of the powdered solids is mainly determined by the nature and pressure of the gas filling the spaces, and is very small if the gas is completely removed.

Silicon Monosulphide. L. CAMBI. (*Chem. Zentr.*, ii, 1863.) Ferrosilicon containing 90 per cent. of silicon was mixed with two parts of powdered sulphur and an electric current of about 80 ampères passed through the mass. After cooling in a current of CO_2, the gray product was treated with water and then evaporated. The non-volatile residue consisted of iron sulphide and undecomposed ferrosilicon. The monosulphide, SiS, was obtained in two forms: a compact, black substance and a yellow powder. The former has a density of 1.853 at 15° C., and sublimes at 940° to 980° C. at 20 to 30 mm. pressure. The yellow monosulphide is always formed when the black modification is sublimed. It is much less stable than the black, rapidly absorbing moisture from the air, and evolving H_2S, and becomes white. It dissolves in alkalies with evolution of hydrogen.

Celtium, a New Element. G. URBAIN. (*Compt. rend.*, clii, 141.)—Mons. Urbain, in the last few years, has approximately isolated a new element, lutécium, from ytterbium, but failed to obtain it in a pure condition for want of sufficient material. To obtain more he treated the earths of gadolinite. In the fractionations by repeated crystallizations, he obtained a few drops of a mother liquor which refused to crystallize. Of course all kinds of impurities accumulate in the mother liquor, so this was treated to eliminate everything but the rare earths, and the purified, perfectly white earth obtained was then examined. spectral analysis revealed the presence of lutécium, a trace of neo-ytterbium, of scandium and negligable traces of calcium and magnesium. There were also very intense rays, which did not coincide with those of any known body. This new element he calls Celtium with the symbol Ct.

VANADIUM ALLOYS.[*]

BY

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THE element Vanadium, while very widely distributed, has only in the last few years been available in sufficient quantities for metallurgical purposes. It is apparently diffused through all primitive granites, and many sedimentary rocks and clays. Its presence has been discovered in many iron ores, and practically all the American magnetites and secondary iron ore deposits contain small amounts. It occurs in larger amounts in many lead ores as the mineral vanadinite, a chloro-vanadate of lead, and until recently this mineral was the principal source of vanadium salts. Vanadium is also found associated with copper, zinc, and uranium ores. In 1905 a very large deposit of a new vanadium mineral was discovered in the Andes of Peru, near Cerro de Pasco, by Don Antenor Rizo Patron. This mineral, known as Patronite after its discoverer, is a sulphide of vanadium containing about 20 per cent. vanadium, and free from the usually associated metals, lead, zinc and copper. · This deposit is the source of the greater part of the vanadium used in producing vanadium alloys to-day.

The element was first discovered by Del Rio in 1801 in the brown lead ores of Zimapan, Mexico, and named by him Erythronium. It was denied a place as a new element and was pronounced a basic chromate by Collet-Descostil in 1805 after examination of the ore sent to the Academy of Sciences by Humboldt. Del Rio himself came to this same conclusion in 1822. Then in 1830 the Swedish chemist Sefstrom discovered a new element in some remarkably soft and ductile iron made from the Taberg iron ores, and named it Vanadium, after the Scandinavian diety Vanadis. Immediately following this discovery Wohler identified the new element, Vanadium in the Zimapan ores as the Erythronium of Del Rio. From this date on scarcely a year has passed without a record of the discovery

[*] Presented at the Meeting of the Mining and Metallurgical Section held Thursday, March 23, 1911.

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of some new mineral, ore or rock containing vanadium, and investigations of its salts. It was soon found to be widely distributed but almost universally in such small quantities that it was classed as a rare element, and sufficient amounts for extensive chemical investigations were hard to obtain.

In 1863 Lewis Thompson suggested that perhaps vanadium has the same effect on iron as nickel, as its discovery was made in an iron of remarkable ductility and softness, and he hoped that more thorough experiments with this important metal would be made. This suggestion, as may be supposed, hardly created even passing comment, as vanadium was still so rare a metal that its salts were counted among the greatest of chemical rarities.

In 1864 Edward Riley discovered vanadium while analyzing some pig-iron smelted from the oolitic Wiltshire ores. He found as high as 0.686 per cent. present and even suggested the utilization of this pig-iron as a source of vanadium compounds. Quite an opposite proposition to that of Thompson's.

During the years 1867 to 1870 Sir Henry Roscoe made his very exhaustive researches on vanadium and its chemical compounds, reducing vanadium for the first time to the metallic state. This metallic vanadium, however, as a matter of fact, contained about 3 per cent. of impurities. Owing to its great affinity for oxygen, nitrogen and carbon at high temperatures and its power of absorbing hydrogen, vanadium has not yet been separated in the pure state. Roscoe's source of supply was the lime precipitate obtained as a residue in extracting cobalt from a sandstone deposit at Mottram, Cheshire, England. While no analysis of the percentage of vanadium in this sand rock is known, the fact that the deposit contained only a few tenths of a per cent. of cobalt gives us an idea of how small a percentage must have been present. It is interesting to note that this deposit was for a time a leading source of supply of vanadium compounds.

Following closely Roscoe's researches came the first industrial application of vanadium, the use of its salts in the manufacture of aniline black. From this date on to 1900 practically the only applications of vanadium were in the manufacture of aniline black, indelible inks, dyeing and calico printing. It was used to some extent also in the ceramic industry on account of the fine gold colored glaze with greenish tinge to be obtained from

the oxides. The two principal sources of supply at this time were the Spanish lead mines and the basic steel slags from Le Creusot Steel Works, France. In 1882 it was discovered that these slags contained slightly over 1 per cent. vanadium, and as lately as 1902 there were produced yearly about 165,000 pounds of oxide from this source, all of which went into the aniline and dyeing industries.

About 1890 vanadium appears to have entered the domain of metallurgy and the production of metallic vanadium, and its alloys attempted with a view to industrial application.

Moissan in 1893 in the course of his researches in the reduction of refractory metals in the electric furnace, undertook the production of metallic vanadium. Owing to its great affinity for carbon his purest metal contained from 4.4 per cent. to 5.3 per cent. of carbon. To produce this he was obliged to have the carbon tube in which the reduction was made filled with hydrogen. According to Moissan, of all the refractory metals he was able to prepare in the electric furnace, vanadium was the most infusible. He discovered while investigating the carbides of vanadium, that notwithstanding its very high melting point, 1680° C., vanadium readily alloyed with iron, copper and aluminum. He produced a ferro-vanadium containing 20 per cent. vanadium and 8 per cent. carbon, and found that the carbon content of the alloy rapidly increased with the length of time it was in the furnace. By replacing iron oxide with copper oxide he produced an alloy of copper and vanadium containing 96.5 per cent. copper and 3.38 per cent. vanadium. This alloy was considerably harder than copper, but malleable and easily filed. By adding a mixture of vanadium oxide and powdered aluminum to a bath of melted aluminum, he produced an alloy with 2.5 per cent. vanadium, and suggested this method as a ready means of producing alloys of refractory metals. Subsequent investigations have shown that vanadium also alloys readily with manganese, nickel, chromium, silicon and other metals.

In the course of his investigations on the carbides of vanadium Moissan found that while there were several carbides CV, CV_2, C_3V_4, and C_2V_3, the one generally formed was CV, containing theoretically 18.97 per cent. carbon and 81.03 per cent. vanadium. He succeeded in producing some of this carbide containing 18.39 per cent. carbon and 81.26 per cent. vanadium.

In 1899 Cowper-Cowles succeeded in depositing metallic vanadium electrolytically, but I have seen no analysis of this metal, and no additional investigations along this line appear to have been made. Slight changes in current density, temperature and concentration of the electrolyte caused precipitation of the oxides instead of metal.

While there appears to be some evidence that the effect of vanadium when added to iron and steel was known to some extent in 1890, the more important investigations recorded are those on armor plate at Firminy in 1896, and a report on vanadium in steel, copper and aluminum alloys by Helouis before the Society for the Encouragement of National Industries, France, the same year. Practically nothing developed from these tests, principally no doubt on account of the high cost of the material and the limited supply in sight. In the case of the Firminy tests great difficulty was experienced in getting the vanadium into the steel, and in fact only one out of the three tests made proved successful. The results of this test, however, were quite conclusive in superiority.

It was not until the more complete and comprehensive investigations of Prof. Arnold in 1900 that vanadium began to receive the attention it deserved as an alloying metal. Arnold's tests were made both upon low carbon and high carbon steels. He found that a 1.25 per cent. carbon steel with 3 per cent. vanadium would cut 75 per cent. more turnings than the same steel with 3 per cent. of tungsten. In the case of the soft steels he found that the elastic limit was raised from 30 to 50 per cent., without impairing their ductility, by the addition of a few tenths of a per cent. of vanadium. He gave it as his opinion that vanadium is undoubtedly the element which together with carbon acts with the greatest intensity in the way of improving alloys of iron, that is to say, in very small percentages. This was just at the beginning of the high-speed tool-steel era, inaugurated by the exhibition of Taylor-White Steel at the Paris Exposition. One of the best of the Taylor-White steels was a chrome-tungsten steel containing 0.30 per cent. vanadium, and to-day practically all the leading brands of high-speed steel contain vanadium.

Following Arnold came the very complete work of Sankey and Smith on chrome-vanadium steels published before the Institute of Mechanical Engineers in 1904, and this might be said to

mark the beginning of vanadium steel as a commercial product. With the discovery in 1905 of the Peruvian deposit, a plentiful supply of vanadium was assured and its use in metallurgy became at once possible.

While vanadium alloys readily with quite a number of metals, by far the most important alloy is with iron, and its greatest application is in the manufacture of alloy steels. In 1905 there were produced about 800 tons of vanadium steel, most of which went into the automobile industry and high-speed tools. Last year I estimate that there were produced over 50,000 tons of vanadium steel, a record that is very creditable considering that there were during the interval three somewhat lean years in the steel industry.

The metal vanadium has an atomic weight of 51.3; specific gravity of 5.5; is non-magnetic; has a high electrical resistivity; melts at 1680° C.: is the most difficult to reduce and the hardest of the metallic elements. Owing to its very high melting point, vanadium, even if it were possible to produce it reasonably pure in the metallic state, would present very considerable difficulty in alloying with other metals. To overcome this difficulty and make it easier to introduce, special alloys rich in vanadium are produced.

Ferro-vanadium is approximately an alloy of two parts iron and one part vanadium, usually ranging from 30 per cent. to 40 per cent. vanadium. Aside from vanadium and iron, the alloy contains some silicon and aluminum, generally less than 2 per cent. of each. It has a melting point of about 1340° C. to 1400° C. The melting point of ferro-vanadium depends both upon the per cent. of vanadium contained and also upon the percentage of other metals present, such as silicon and aluminum. The specific gravity is 7.34. The alloy is hard, but not brittle, and is crushed with considerable difficulty. Armor plate and manganese steel jaw plates are worn out with considerable rapidity in the crushers.

In case the alloy is prepared by the electric furnace process, it will contain from 1.5 to 6 per cent. or more of carbon. This carbon is present in combination with vanadium in the proportion of about 4.25 per cent. vanadium for each per cent. of carbon. Carbide of vanadium will not alloy with iron, and on adding ferro-vanadium containing this to steel, the carbide is either all

lost by rising to the surface, or some of it may remain in the steel in mechanical suspension, giving rise to hard spots and otherwise impairing the physical qualities of the steel. On this account most of the ferro-vanadium is made by the well-known aluminum reduction process, which produces carbon-free alloys.

I have taken a ferro-vanadium containing 6 per cent. carbon and treated it in the finely powdered condition for a week with hydrochloric acid, drawing off and renewing the acid daily. The acid from each treatment was tested for vanadium, but no trace was found. By the end of the week all the iron had been apparently dissolved out of the sample, and the residue on analysis was found to contain practically nothing but carbon and vanadium, showing that in the case of this ferro-vanadium no vanadium had alloyed with the iron.

The vanadium is extracted from the ores by chemical means and converted into oxide for reduction. This oxide is mixed with iron oxide and powdered aluminum and the mixture reduced in large magnesite lined crucibles. The whole mix is not usually fired at once as in the case of the well-known Goldschmidt Thermit Process, but is generally fed into the crucible in small amounts. In this way the reaction is less violent, and under better control.

Vanadium is undoubtedly the most powerful metal yet discovered for alloying with steel. Its intensifying effect on the other elements in the steel, carbon, silicon, manganese, chromium, etc., is so great that although these elements are usually present in greater amounts, the steel is improved and changed to such a degree that it is designated as vanadium steel, chrome-vanadium steel, etc. To quote still further Professor Arnold's opinion of the effect of vanadium on steel: He was of the opinion that vanadium combined to form a double carbide of iron and vanadium, and it seemed to have not only a chemical, but a physical influence in promoting the even distribution of the carbon, and retarding constitutional segregation. From this and other experimental evidence there is the strongest reason to believe that very small percentages of vanadium will largely enable steel to resist that deterioration which under continued vibration leads to brittleness. This opinion of Professor Arnold has been entirely confirmed by the record of vanadium steels during the ten years that have since elapsed, and they have well earned the name of

" anti-fatigue " steel. Two to three-tenths of a per cent. of vanadium augments the properties produced by quenching, elastic limit, tensile strength and hardness, without sensibly modifying the ductility of the annealed steel.

In addition vanadium through its affinity for oxygen and

TABLE I.

BALLISTIC TEST SPECIFICATIONS FOR STANDARD NICKEL STEEL PROTECTIVE DECK PLATING.

Guage of plate, inches.	Caliber of gun, inches.	Striking velocity, foot-seconds.	Striking energy, foot-tons.	Angle of impact, degrees.
1	4	1912	110	7
1½	6	1775	275	7
2	6	1850	300	7
2½	6	1925	415	9
3	6	2000	450	9

TABLE II.

BALLISTIC TEST SPECIFICATIONS FOR CARNEGIE "SPECIAL TREATMENT" STEEL PROTECTIVE DECK PLATING.

Gauge of plate, inches.	Caliber of gun, inches.	Striking velocity, foot-seconds.	Striking energy, foot-tons.	Angle of impact, degrees.
1	6	1330	192	9
1½	6	1910	398	9
2	8	1540	650	9
2½	8	1870	960	9
3	8	2160	1270	9
3½	8	2410	1580	9
4	8	2640	1900	9

CARNEGIE "SPECIAL TREATMENT" STEEL APPROXIMATE PHYSICAL CHARACTERISTICS.

Ultimate Tensile Strength...................... 130.000 lbs. per sq. inch.
Elastic Limit.............................. 118.000 lbs. per sq. inch.
Elongation in 2 inches........................ 19 per cent.
Reduction of Area........................... 50 per cent.

nitrogen acts as a scavenger in the manufacture of steel. On account of its price, however, it is not used primarily for this purpose, and the steel makers' aim is to sacrifice as little for this purpose as possible.

As we have already seen, one of the earliest applications of vanadium to steel considered was for war material, and some thin plates were actually tested out by the Firminy Steel Works in 1896. It is not surprising then that when an assured supply of vanadium at a reasonable price became available its applica-

TABLE III.

Standard Nickel Steel Protective Deck Plate No. 262580-A (Two Inches Thick) Tested at Indian Head Proving Grounds, February 19, 1907.

	Normal Impact		
	Round No. 1.	Round No. 2.	Round No. 3.
Gun....................	3-inch	3-inch	3-inch
Weight of projectile........	13 lbs.	13 lbs.	13 lbs.
Striking velocity	1015 ft.-sec.	1065 ft.-sec.	1165 ft.-sec.
Penetration...............	Complete	Complete	Complete

TABLE IV.

Carnegie "Special Treatment" Steel Protective Deck Plate No. 333-E (Two Inches Thick) Tested at Indian Head Proving Grounds, December 28, 1907.

	Normal Impact		
	Round No. 1,	Round No. 2.	Round No. 3.
Gun....................	3-inch	3-inch	3-inch
Weight of projectile........	13 lbs.	13 lbs.	13 lbs.
Striking velocity	1632 ft.-sec.	1889 ft.-sec.	2074 ft.-sec.
Penetration...............	$\frac{1}{15}$ inch	$\frac{5}{16}$ inch	$\frac{3}{4}$ inch

tion to steel for war material, especially armor plates, was promptly taken up. The combined properties of great hardness and toughness possessed by vanadium alloy steels being just what is necessary for armor plate, to-day all the protective deck plate, gun shields, and plate for splinter bulk heads are made of vanadium alloy steel. By the use of vanadium in these plates the

Government has been able to raise the specifications for ballistic tests very materially. Through the courtesy of the Carnegie Steel Company, I am able to show by means of tables and curves what these increased requirements are and how great the superiority of the vanadium steel plates are over those furnished under the old specifications. Tables I and II show comparative tests made on two protective deck plates, one of the standard nickel steel, and the other vanadium steel. In these tests the impact was normal, while in the regular test of such plates the impact is at a small angle. The size of gun and weight of projectile were the same for both plates, but the striking velocity was much greater for the vanadium plate. The penetration was complete for each round in the case of the nickel steel plate, while the greatest penetration of the vanadium steel plate was $\frac{3}{4}$ of an inch, by a shot with nearly 80 per cent. more striking velocity.

Tables III and IV give the old ballistic test specifications for nickel steel protective deck plates, and the new specifications for the vanadium steel plates. To pass test, the plates must not be penetrated, nor show any through cracks. The curve (Diagram I) shows graphically these requiremets and gives a very good idea of the tremendous superiority of the new plates over the old ones. The upper curve is the vanadium steel and the lower curve the nickel steel formerly used. The plates represented in each test passed specifications.

Tests now under way show that vanadium steels retain a much larger proportion of their hardness and strength at elevated temperatures than other steels. This has also been confirmed by the behavior of vanadium steels in service, notably in gas engine exhaust valves and high-speed tool steels. This property would indicate that vanadium steel is the best material to resist erosion of gun tubes and rifle barrels. The erosion of gun tubes by smokeless powder is a very serious matter, and one that is receiving very much consideration to-day. As a matter of fact, vanadium steel is already being used to a considerable extent for rifle barrels.

The vanadium alloy steels containing the highest percentage of this element are the so-called high-speed tool steels. These are medium carbon, chrome, tungsten steels containing from 0.5 to 1 per cent. of vanadium. The effect of the vanadium has been to

increase the efficiency of this steel about 30 per cent., due very probably in a great measure to the property mentioned just now of vanadium steels retaining a large proportion of their strength

DIAGRAM I.

							8"GUN·9% 250LB.SHELL 2640FT.SEC.	2000
								1900
								1800
								1700
								1600
						8"GUN·9% 250LB.SHELL 2410FT.SEC.		1500
								1400
								1300
					8"GUN·9% 250LB.SHELL 2160FT.SEC			1200
								1100
								1000
				8"GUN·9% 250LB.SHELL 1870FT.SEC				900
								800
								700
			8"GUN·9% 250 LB.SHELL 1540FT.SEC					600
								500
	6"GUN·9% 100LB.SHELL 1910FT.SEC.				6"GUN·9% 100LB.SHELL 2000 FT.SEC.			400
				6"GUN·9% 100LB.SHELL 1925 FT.SEC.				300
6"GUN·9% 100LB.SHELL 1330FT.SEC.		6"GUN·7% 100LB.SHELL 1775 FT.SEC.	6"GUN·7% 100LB.SHELL 1850 FT.SEC.					200
	4"GUN·7% 33LB.SHELL 1912 FT.SEC.							100

STRIKING ENERGY IN FOOT TONS

GAUGE OF PLATES
THICKNESS IN INCHES → 1"   1½"   2"   2½"   3"   3½"   4"
WEIGHT PER SQ.FT. → 40 LB.   60 LB.   80 LB.   100 LB.   120 LB.   140 LB.   160 LB.

and hardness at high temperatures. Practically all of the highest grade high-speed tool steels contain vanadium.

The vanadium alloy steels having the widest applications are what might be termed alloy machinery steels. These are chrome-vanadium, nickel-vanadium, and chrome-nickel-vanadium, and

were developed, one might almost say, to meet the especial requirements of the automobile industry. They found their first application in this industry, then in its infancy, rapdly finding out that ordinary machinery steel could not meet the requirements. The railroads also promptly began testing out vanadium steel for special parts, and are now extensive users of these steels. To-day vanadium steels have a very wide and rapidly increasing application. Like all other alloy steels, they should only be used in the heat-treated condition in order that the full extent of their superior qualities may be developed.

I would like to emphasize this matter of heat treatment. This is one of the most important operations to which steel is subjected; in a way it is the most important, as it is generally the final one. It is essential that the work be done by skilful men, supplied with accurate pyrometers and well designed and constructed furnaces capable of maintaining a uniform heat and of being easily regulated. The quenching tanks should be conveniently located and of suitable size for the work to be treated, and provisions should be made for maintaining the quenching medium at approximately a uniform temperature. Most essential of all, the man in charge of the heat treatment should know the composition of the steel and the temperatures best suited to bring out the desired properties.

The most important and widely used of these steels are the chrome-vanadium. These have been developed in three distinct grades or types, generally known as Types " A," " D," and " E," typical analyses being as follows:

	" A "	" D "	" E "
Carbon	0.25 per cent.	0.45 per cent.	0.15 per cent.
Manganese ...	0.45 per cent.	0.80 per cent.	0.30 per cent.
Chromium ...	0.80 per cent.	1.00 per cent.	0.30 per cent.
Vanadium ...	0.18 per cent.	0.18 per cent.	0.12 per cent.

In addition to these there are rapidly coming into extensive use low nickel-chrome steels, with a range of composition about as follows:

Carbon	0.25 to 0.45 per cent.
Manganese	0.50 to 0.70 per cent.
Nickel	1.00 to 1.50 per cent.
Chromium	0.60 to 0.80 per cent.
Vanadium	about 0.18 per cent.

These steels are free from the treacherous qualities of the high nickel-chrome steels, and are destined to replace them to a great extent.

Type " A " steel is essentially an oil-tempering forging steel, though it is much used for casehardening gears, and other parts where great strength of core is required. The forgings are usually heat-treated to give an elastic limit of 100,000 to 110,000 pounds per square inch, with a tensile strength of 120,000 to 130,000 pounds per square inch; an elongation in 2 inches of 18 per cent. to 20 per cent., and a reduction of area of about 60 per cent. Much higher elastic limits are regularly obtained for crank shafts, propeller shafts, etc., when desired. The influ-

FIG. 1.

ence of the size of the forging on the physical properties to be obtained by heat-treatment is, of course, very important, and tests of heat-treated bars of small diameter are frequently criticized as representing results unattainable in commercial forgings. However, these tests serve a very useful purpose as a means of comparing different steels under similar conditions and also as a guide in the heat treatment of forgings. For the medium size sections used in the automobile industry the high results are quite readily attainable. In the case of forgings of large section, such as car and locomotive driving axles, a considerable reduction from such figures naturally must be expected, but in the case of the vanadium steels this reduction is not so great as for steels without vanadium.

I will not attempt in this paper to go extensively into details of heat-treatment and tests of vanadium steels, but will show by means of a few illustrations some of the tests that have been made on commercial material. These tests will give an excellent idea of the remarkable toughness of this high-strength steel.

Fig. 1 is an automobile crank shaft that has been distorted by repeated blows of a 2500-pound steam-hammer without sign of fracture. An excellent 0.35 per cent. carbon steel shaft was subjected to like test but could not be distorted to the same extent without fracture, the force exerted to an equal number of blows being only one-fourth that required to distort the Type "A" vanadium steel shaft.

FIG. 2.
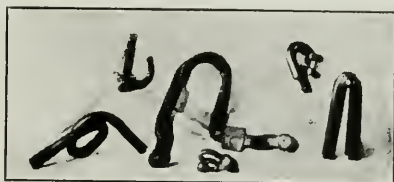
Vanadium steel automobile forgings, physical tests: elastic limit, 110,000; tensile strength, 130,000; elongation in 2 inches, 20 per cent.; reduction of area, 57 per cent.

Fig. 2 shows a group of distorted automobile forgings, including an axle, connecting rod, transmission shaft, etc.

Fig. 3 is a locomotive side rod that was doubled over on itself by means of a falling weight of 4000 pounds used to break up scrap.

FIG. 3.
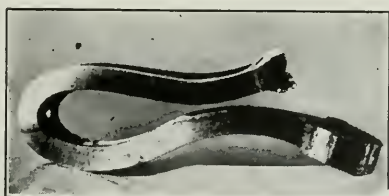
Vanadium steel side rod, physical properties: elastic limit, 101,000; tensile strength 125,000; elongation in 2 inches, 20 per cent.; reduction of area, 55 per cent.

Fig. 4 is a locomotive piston rod, both ends of which have been machined down for test as shown. One end was tested by giving it one complete twist, the other was pulled in the test machine until just about ready to break—the results given are from this test.

Fig. 5 is a locomotive driving axle, 9½ inches in diameter. bent through 180 degrees without fracture. A carbon steel

axle with the same elastic limit would not stand bending over about 7 to 10 degrees. The average tests of 185 driving axles was:

Elastic limit .... 82,480 pounds per square inch.
Ultimate strength .... 109,540 pounds per square inch.
Elongation in 2 inches........ 21.3 per cent.
Reduction of area............. 57.3 per cent.

Elastic limits of 120,000 pounds per square inch with 15 per cent. elongation in 2 inches and over 40 per cent. reduction of area can be obtained in these driving axles if desired.

It is well to know that for the past six or seven years the railroads and the Government have been jointly investigating the problem of safe transportation of explosives. Classed among the explosives are the commonplace seamless cylinders of compressed

FIG. 4.
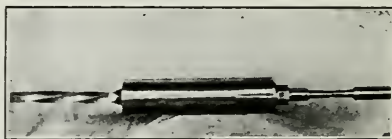
Vanadium steel piston rod, physical properties—actual test: elastic limit, 101,650; tensile strength, 124,875; elongation in 2 inches, 21.50 per cent.; reduction of area, 37.16 per cent., and not broken.

carbonic acid gas, oxygen and other gases. These not infrequently burst through overcharging, increased pressure due to exposure to heat, etc. The great danger lies in the flying pieces of the cylinders when they burst. It is very desirable that these cylinders be made from a strong steel that will not shatter upon bursting. At the same time lightness of cylinder is very desirable from a commercial stand-point. Low carbon steel, annealed, will not shatter, but in order to obtain the requisite strength to withstand the gas pressure safely, the cylinders become too heavy.

About eighteen months ago the National Tube Company made a very extensive series of comparative tests to determine if it were possible with any steel to meet all the requirements; freedom from shattering, strength and lightness. Through the courtesy of this company I am able to show you photographs of tested cylinders from several of these series of tests. The low carbon cylinders shown in Fig. 6 are standard cylinders used for

oxygen, 7⅝ inches outside diameter, 43 inches long, walls ⅜ inch thick and weigh 108½ pounds on an average. They have

FIG. 5.

Vanadium steel locomotive driving axle, 9½ in. diameter, bent cold under 14,000 ton press; elastic limit, 75,000 pounds; tensile strength, 100,000 pounds; elongation in 2 inches, 20 per cent.; reduction in area, 50 per cent.

FIG. 7.

FIG. 6.
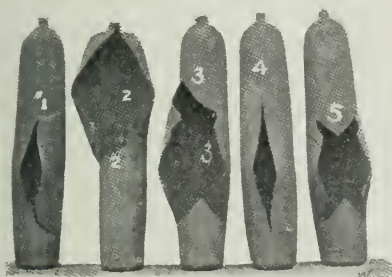
an average yielding pressure of 3600 pounds per square inch and a bursting pressure of from 6600 to 7000 pounds per square inch.

Fig. 7 shows annealed high carbon (0.41 per cent.) cylinders frequently used for carbonic acid gas. These cylinders are larger and lighter than the low carbon ones. The dimensions are 8½ inches outside diameter, 51 inches long, wall ¼ inch thick, and average 94½ pounds in weight. The average yielding pressure was 3000 pounds per square inch and the bursting pressure from 5000 to 5900 pounds per square inch.

Fig. 8 shows annealed high-silicon (1 per cent.) steel cylinders of the same size and weight as the high carbon cylinders. These had an average yielding pressure of 3800 pounds per square inch, and a bursting pressure of from 5000 to 5950 pounds per square inch.

Fig. 9 shows chrome-vanadium steel cylinders of the same length and thickness of walls, but $^3/_{16}$ inch larger in diameter,

FIG. 8.

FIG. 9.
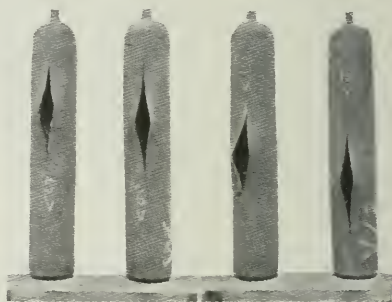
and had an average weight of 105 pounds. These cylinders were all double treated, that is, quenched and then annealed or drawn back. The yield pressure for the cylinders shown ranged from 6200 to 8200 pounds per square inch, and the bursting pressure from 6450 to 8500 pounds per square inch. As a result of these tests, the Government is now specifying chrome-vanadium steel seamless air-flasks for all naval purposes, and doubtless gas cylinders will eventually be made of this material in order to meet future transportation requirements.

Type " D " chrome-vanadium steel is used principally for springs, oil-tempered gears and pinions. It is also used in the mild or lower carbon grades for automobile rear axle shafts, crank shafts, and other parts where a high elastic limit is desired.

The higher drawback temperature at which the same elastic limit can be obtained makes it preferable to the Type " A " steel under some conditions. The high elastic limit coupled with great tough-

FIG. 10.

SPRING DEFLECTIONS.
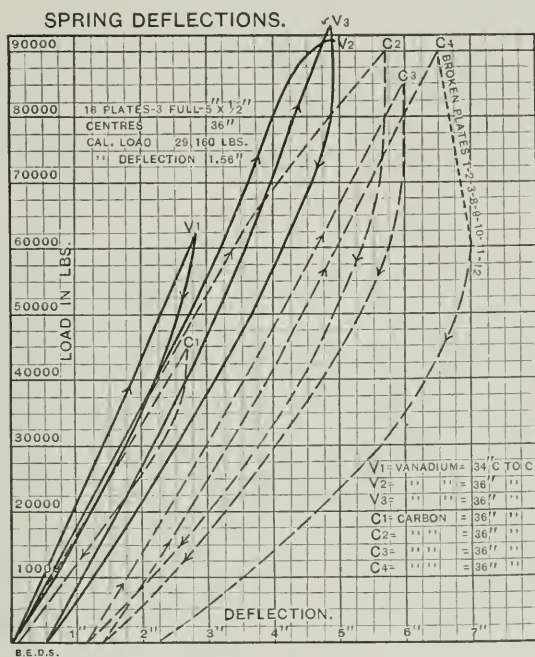
COMPARATIVE TESTS ON VANADIUM AND CARBON STEEL SPRINGS.

TESTED BY THE AMERICAN LOCOMOTIVE COMPANY.

THE VANADIUM SPRING WAS TESTED:

1. To 62,700 lbs. with 34 inch centres.
2. To 92,000 lbs. with 36 inch centres.
3. To 94,000 lbs. with 36 inch centres.
On second test, elastic limit was reached at 85,000 lbs. or 234,500 lbs. fibre stress with permanent set of 0.48 inches.
The third test was repeated three times without the least variation from recorded heights.

THE CARBON SPRING WAS TESTED:

1. To 44,000 lbs. with 36 inch centres.
2. To 89,280 lbs. with 36 inch centres.
3. To 84,520 lbs. with 36 inch centres.
4. To 89,280 lbs. with 36 inch centres.
On second test, elastic limit was reached at 65,000 lbs. or 180,000 lbs. fibre stress with permanent set of 1.12 inches.
On third test, it took an additional set of 0.26 inches and on fourth test, plates 1-2-3-8-9-10-11-12 failed at the centre.

STATIC TEST ON PIECE CUT FROM LEAP OF SPRING.

Elastic limit, 227,100; ultimate strength, 237,500; ratio, 96 per cent.; elongation 2 inches, 10 per cent.; contraction of area, 35 per cent.

TYPE " D " VANADIUM SPRING STEEL.

ness, and the more rapid recovery of vanadium steels from over-strain makes Type " D " the ideal steel for springs.

Fig. 10 shows a comparative test of two locomotive springs,

one from standard carbon spring steel, the other from Type " D " vanadium steel.

Fig. 11 illustrates very well the remarkable toughness of vanadium steel. These springs were taken from wrecked automobiles.

Fig. 12 shows very clearly the importance of heat-treatment. These two fractures are from the same plate of steel from a defective semi-elliptic spring. The coarse fracture shows the original condition of the steel in the spring, and readily accounts for the failure; the other fracture shows the steel as it should have been.

Type " D " chrome-vanadium steel is showing up remarkably well in locomotive tires and solid-rolled-steel wheels, and there

FIG. 11.
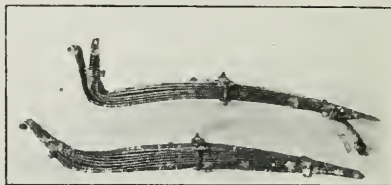
Vanadium steel springs: bent in an automobile wreck.

is already some demand for vanadium tires and wheels for severe service.

An interesting example of the application of Type " D " steel is for hot and cold saws in steel mills. A hot saw running 1100 r.p.m., 17300 feet per minute, cutting 15-inch to 24-inch I-beams, made a record of 1800 tons with one dressing. The average for carbon steel saws was 125 tons. Another saw cutting slabs 5 inches thick by 30 inches wide made 585 cuts. The average for the carbon steel saws was 9 cuts. A high-speed disc cold saw cut 1890 gross tons, equivalent to the work of 70 standard saws.

Type " E " steel is essentially a casehardening steel, and is used extensively for clash gears. It is also an excellent steel in its normal condition for bolts, rivets, and plates for pressed frames. Casehardened, it gives a strong, tough, hard, and closely coherent case, with a strong ductile core. These points are well shown in Fig. 13.

The use of vanadium in steel is not confined to what are known as the alloy steels. A very large tonnage of steel castings is being made to-day containing vanadium. One of the early applications of vanadium was in cast steel frames for locomotives. For this purpose vanadium steel has made an enviable reputation, as out of some 1500 frames there have been less than six known failures. Some of these frames have been put under engines that have had bad records as frame breakers. The elastic limit of vanadium steel castings averages about 30 per cent. to 40 per cent. greater than for plain carbon castings of the same

Fig. 12.
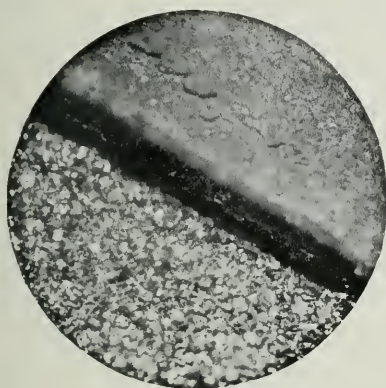
Diam. 13.

Fig. 13.
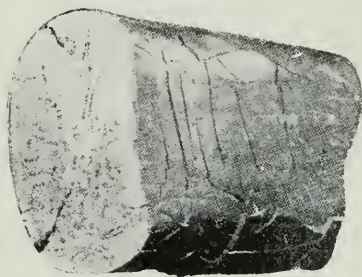
Casehardened vanadium steel. This steel was casehardened in the perfect round section, and after quenching, was beaten out cold to the shape shown, under a heavy power hammer.

composition. The dynamic strength is from 50 per cent. to 75 per cent. greater. Vanadium cast steel is also being used to a considerable extent for rolling mill pinions and is giving from two to three times the life of ordinary carbon cast steel pinions.

Fig. 14 shows a locomotive frame tested by a falling weight; and Fig. 15 a rolling mill pinion after having outworn a 3½ per cent. nickel steel pinion. This pinion has since outworn a second nickel steel pinion.

There are many vanadium steel castings made by the crucible process, and Fig. 16 illustrates the remarkable toughness combined with high strength that is being obtained through the addition of about ¼ per cent. of vanadium.

While vanadium alloys readily with nickel, chromium, manganese, silicon, copper, aluminum and some other metals, only the alloys of the last two mentioned apparently have any indus-

FIG. 14.
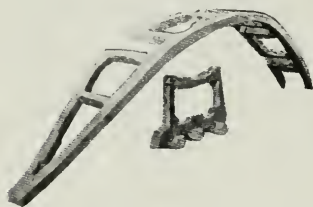
FIG. 15.

Vanadium steel engine frame section. Subjected to 20 blows from a 5000 lb. ball or trip dropping from a height of 18 ft. in the clear; supports four feet apart. Regular steel frame section invariably breaks on either the first or second blow.
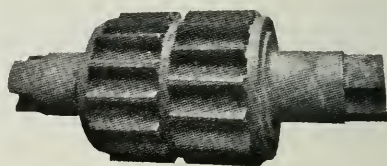
Vanadium steel mill pinion, 46 inch diameter. A 3½ per cent. nickel-steel pinion, made by the same firm to the same pattern, and placed in companion service in the same rolling mill, was worn out completely, while the vanadium steel pinion continued in service and presented this appearance after rolling 100 per cent. more tonnage than the nickel-steel pinion.

trial application. It is possible that ferro-vanadium containing high percentages of chromium, manganese, or silicon might be of some advantage in steel making by reducing the amount of

FIG. 16.
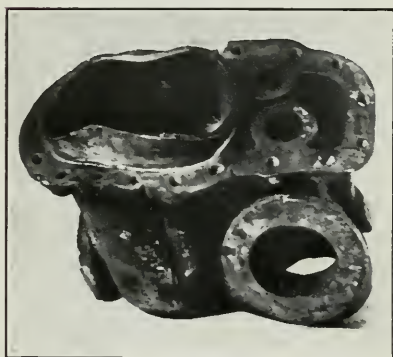
FIG. 17.

Vanadium crucible steel casting cylinder for torpedo. Physical test: elastic limit, 65,000 pounds; tensile strength, 80,000 pounds; elongation in 2 inches, 22 per cent.; reduction in area, 43 per cent.
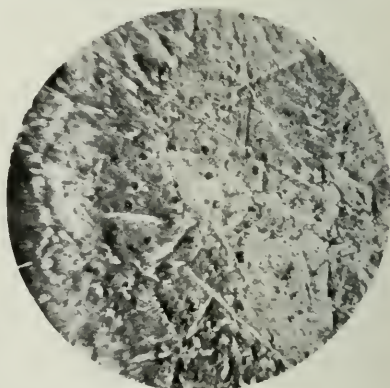
Diameter 210.

these metals to be added in the form of other alloys, but as yet there has been no demand for such special alloys.

Cupro-vanadium usually contains about 3 per cent. of vana-

dium. The eutectic alloy contains about 7 per cent. vanadium. Mixtures containing a high percentage are not desirable on account of the very high melting point and consequent difficulty in getting it into the alloys.

Vanadium has as yet hardly entered the field of non-ferrous alloys, although I firmly believe that in the near future it will be found occupying almost as prominent a place in these alloys as it does at present in steel. The principal reason for this apparent lack of progress has been due largely to the difficulty of producing cupro-vanadium free from undesirable metals, notably iron and aluminum.

Vanadium has a very high electrical resistance, and the addition of only a few hundredths of a per cent. reduces the conductivity of copper in a very marked degree. A few hundredths of a per cent. will increase the elastic limit, tensile strength and ductility of copper from 10 per cent. to 20 per cent.

About the first reference to the use of vanadium in non-ferrous alloys is contained in the article previously referred to by Helouis. He produced some experimental bronzes, notably an aluminum bronze, 94.5 per cent. copper and 5.5 per cent. aluminum with 0.5 per cent. vanadium, which gave a tensile strength of 97,336 as against 49,770 pounds per square inch for the same alloy without vanadium.

Vanadium has a very similar effect on the copper alloys that it has on steel. It increases both the elastic limit and tensile strength very materially and does not impair the ductility. Usually the ductility is increased. A recent test of vanadium in a common brass or Muntz metal, 60 per cent. copper, 40 per cent. zinc, gave the following results:

	WITHOUT VANADIUM.	WITH VANADIUM (TRACE ONLY).
Ultimate strength	38,000 pounds	49,000 pounds
Elongation in 2 inches	28 per cent.	45 per cent.
Reduction of area	30 per cent.	42 per cent.

The increase in resiliency by tests on notched bars was a little over 80 per cent.

Tests of vanadium in manganese bronze gave the following results:

TESTS.

	MANGANESE BRONZE.	MANGANESE-VANADIUM BRONZE.
Elastic limit	30,560 pounds	50,560 pounds
Ultimate strength	54,160 pounds	81,440 pounds
Elongation in 2 inches......	22 per cent.	12 per cent.
Reduction of area..........	18 per cent.	14 per cent.

COMPOSITION.

	MANGANESE BRONZE.	MANGANESE-VANADIUM BRONZE.
Copper	58.81 per cent.	58.56 per cent.
Zinc	38.08 per cent.	38.54 per cent.
Aluminum	1.22 per cent.	1.48 per cent.
Manganese	0.69 per cent.	0.48 per cent.
Iron	0.84 per cent.	1.00 per cent.
Vanadium	——	0.03 per cent.

The micro-structure of these bronzes also shows a very marked difference. Fig. 17 is the bronze without vanadium and Fig. 18 the one with vanadium. Magnification, 210 diameters in each case.

A very considerable amount of vanadium bronze is being made of a composition similar to manganese bronze, without manganese. This bronze is very strong, forges readily and resists corrosion to a very high degree. It is being used extensively for marine work, especially in torpedo and submarine boats. The torpedo tubes, Fig. 19, are made entirely of this metal, and parts such as exhaust headers, valves, and air cylinders to withstand heavy pressures. A cylinder 3 inches in diameter, 15 inches long, and walls $^9/_{16}$ inch thick has stood up under 9000 pounds water pressure. Tests of this bronze both cast and cold drawn into rods and wire are as follows:

	CAST.	COLD DRAWN	
		5/8 IN. ROD.	3/8 IN. WIRE.
Elastic limit	28,500 pounds	80,000 pounds	81,500 pounds
Ultimate strength	71,000 pounds	92,000 pounds	100,700 pounds
Elongation in 2 inches..	32.0 per cent.	11.5 per cent.	12.0 per cent.
Reduction of area......	27.8 per cent.	29.3 per cent.	33.6 per cent.

Fig. 20 shows the micro-structure of the cast bronze, magnification 210 diameters.

The possibilities of vanadium in bearing metals, both bronze

and babbitt I believe to be great. Work along this line has made little progress largely owing to the fact that the vanadium alloys at present available contain aluminum, and this element and lead

FIG. 18.
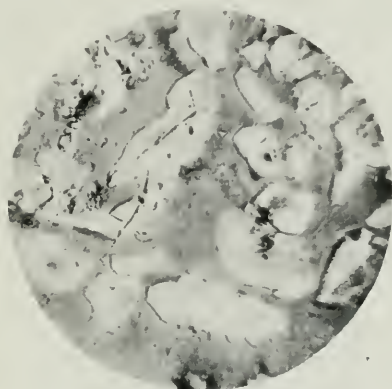
Diameter 210.

FIG. 19.
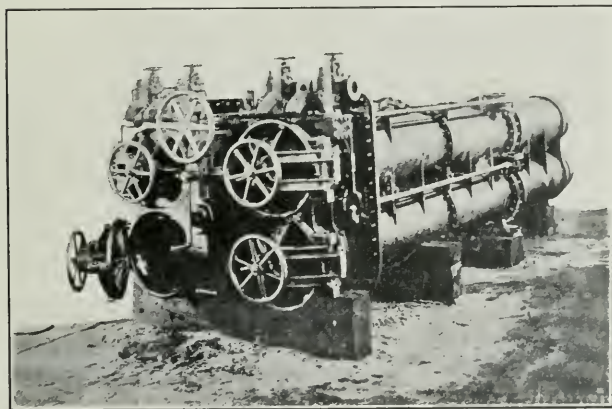
Torpedo tubes made entirely of Victor vanadium bronze.

are quite antagonistic towards each other. I have a report of a large, circular step-bearing in a plate-glass grinding machine that encourages me in my belief, that vanadium will improve the quality of the bearing alloys. These bearings are subject to

a load of 900 to 1000 pounds per square inch and make about 30 r.p.m. It has always been difficult to get a bearing metal hard enough to stand this pressure. This vanadium bearing metal was practically the standard American car journal bronze with approximately 0.05 per cent. vanadium added, and the bearing stood up twelve months with no appreciable wear.

Aluminum and vanadium readily alloy as was discovered by Moissan in 1896. Moissan's alloy contained 2.5 per cent. of vanadium, was stronger and a little harder than pure aluminum. Helouis in the article previously referred to made mention of an alloy of aluminum and 1 per cent. of vanadium which had a

Fig. 20.

tensile strength of 24,174 pounds per square inch. He also called attention to the remarkable sonority of these alloys. Matignon and Mounet produced an alloy of definite atomic composition, AV, containing 32.81 per cent. aluminum and 67.87 per cent. vanadium. The principal application of almino-vanadium will be as a means of introducing vanadium into aluminum and aluminum alloy castings, wire, sheets, etc., and consequently a low melting alloy will be required. The melting point rises of course with the percentage of vanadium. Recent experiments indicate that an alloy of from 5 per cent. to 10 per cent. of vanadium will prove most satisfactory. There is every indication that the use of vanadium in aluminum alloy castings will very considerably increase the strength and ductility.

THE HANDLING, TRANSPORTATION, AND STORAGE OF PERISHABLE FOODSTUFFS.*

A Review of the Work of the Food Research Laboratory, Bureau of Chemistry, U. S. Department of Agriculture.

(*Contribution from the Food Research Laboratory, Bureau of Chemistry, U. S. Department of Agriculture.*)

BY

JOSEPH SAMUEL HEPBURN, A.M., M.S.

PART I.

The Function and Equipment of the Laboratory and a Resume of the Researches Carried Out Therein.

DURING the year 1904–05 there was considerable agitation in the public press on the subject of foodstuffs, especially poultry and eggs, kept in what is commonly termed "cold storage," an elastic phrase in the popular mind and one which is commonly used to account for almost any undesirable condition observed by the consumer when buying perishable produce. So atonishing were the statements made by both the opponents and the advocates of "cold storage" that it seemed advisable for the Federal Government to make an impartial study of the question, that the consumer might not be injured by deleterious products on the market, and that the industries depending upon artificial refrigeration might be upheld if found worthy.

Accordingly the nucleus of the Food Research Laboratory, Bureau of Chemistry. U. S. Department of Agriculture, was established.

In the beginning it consisted of a single worker in a single room, and a part, only of that worker's time was given to the subject. Realizing that the chemical and bacteriological problems involved must be traced simultaneously, and that the funda-

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mental principles governing chemical changes and bacterial growth at low temperatures must be studied first in a medium which could lend itself to such investigation, the one worker in the one small room selected milk as the starting point. The fact that chemical changes did not cease, even when the temperature of the milk was below its freezing point, and that bacterial life was not extinguished—though both these processes were greatly slowed, was recorded in the paper published in 1908 in the *Journal of Biological Chemistry.*

Before the actual publication of this pioneer work, however, the study of poultry kept hard frozen for prolonged periods was begun. Cold storage warehouses, through the American Warehousemen's Association, were put at the disposal of the Department and all their facilities offered for the acquisition of knowledge concerning the changes in foodstuffs while hard frozen. At first the products found in the warehouses, and of which only a warehouse history could be obtained were examined. Such work, while giving information regarding the existing condition, furnished no way of determining previous treatment, nor did it tell what changes actually occurred during the freezing period, as differentiated from the fore period.

Therefore, it was necessary to prepare and freeze samples so that every detail of the preparation for storage should be known.

The analytical results from these birds of known history gave indispensable information, but still they were not adequate to cause a betterment of the industry and an improvement in the consumer's food supply. To accomplish this the laboratory—for by this time the staff had increased to chemists, bacteriologists, histologists, an artist, a stenographer and helpers, and appropriate laboratory quarters had been supplied—obtained the co-operation of every department of the poultry handling industry of the country, including packers, carriers, warehousemen, commission men and retailers. Every assistance and courtesy possible has been extended to the laboratory in this investigation. Every facility and all the trade knowledge possessed by the industry has been at our disposal. A realization that such a study on the part of the Federal Government meant incalculable advantage to the handlers of poultry and eggs, and ultimately to the handlers of all perishable products, has produced an

enthusiasm in bettering conditions and a keenness in seeking and applying advantageous knowledge that is almost phenomenal in any industry, and especially striking in such a scattered unorganized army as that which forms the poultry industry.

Along these broad lines the research work of this laboratory is now progressing. We are studying, with every assistance that modern science can give problems which are eminently practical and which mean betterment to both producer and consumer. The modus operandi by which we are seeking to attain these ends is set forth in the following pages.

In the course of these researches, old methods of analysis have been modified; new methods have been devised which are rapid yet very delicate; and the methods and machinery of physical chemistry have frequently been utilized. Since a change in chemical composition is closely related to an alteration of the physical structure, histological examinations of tissue have been carried out. Moreover, certain chemical decompositions are due to the action of lower organisms—bacteria, moulds and yeasts—hence the study of the number and species of bacteria in flesh have formed a large part of the work. Tissue enzymes play a rôle in the natural changes in foodstuffs, therefore, investigations in the field of zymochemistry have been undertaken. In this way the sample may simultaneously become the subject of chemical, histological and bacteriological examination, and may also be tested for various enzymes.

These studies have been carried out on chickens, eggs and milk. It is the purpose of this paper to describe the laboratory and its equipment, to review the researches carried out therein, and to give a resumé of the results obtained.

The chemical analysis of an animal foodstuff falls into two parts, the study of the fat, and the study of the flesh; the latter is subdivided into the general analysis and the separation and determination of the various proteins.

THE GENERAL ANALYSIS.

The general analysis consists of the determination of the total solids, water, fat, ash, protein and creatin. It serves as a check on the detailed analysis of the flesh, for the sum of the percentages of water, fat, ash and the two forms of nitrogen (protein and amino acid or creatin) should be approximately

100.   Moreover the general analysis will reveal certain gross changes in chemical composition, for instance, during storage in the frozen condition the amount of water in the flesh of chickens decreases with a consequent rise in the total solids.

PROTEIN ANALYSIS.

In the detailed analysis of flesh from the food view point it is customary to determine the total content of nitrogen, the total nitrogen of the aqueous extract and each of the constituents of

Fig. 1.
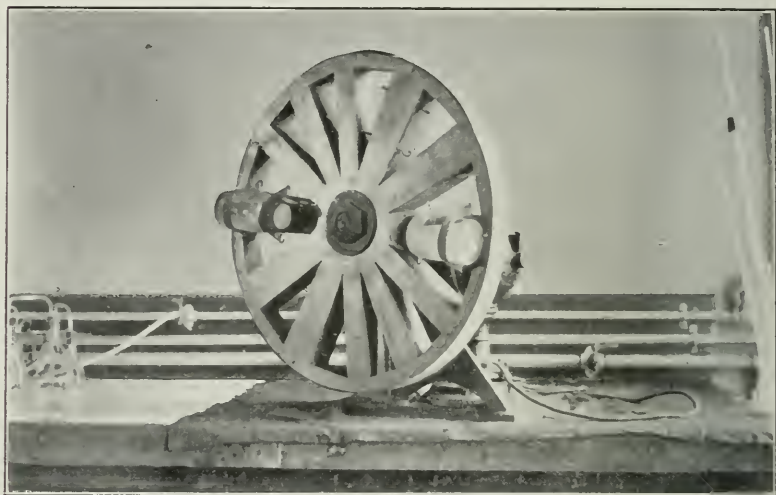
Shaking machine with bottles attached. Broad rubber bands are attached to the hooks on the side of the spokes, and pass over the bottles, which are thus held firmly in place upon the front of the wheel. The bottles are of 250 c.c. capacity and are provided with rubber stoppers. The contents are in two layers, the lower is the meat, the upper the aqueous extract.

that extract, *i.e.*, the nitrogen present in the form of coaguable protein, as albumoses, peptones, and amino acids. In the preparation of the aqueous extract of chicken flesh certain difficulties arose which were overcome by the use of a shaking machine and a centrifuge built especially for the purpose. The shaking machine is an upright wheel driven by a motor. The bottles containing meat and water are fastened to the spokes of the wheel, which is then revolved at such a speed that the contents of the bottles are gently agitated; the soluble constituents of the

flesh dissolve, but the motion is so gentle that no emulsion
is formed. In order to collect the insoluble portion of the
meat into a compact mass, and thus insure rapid filtration of
the extract, the bottles are transferred to the centrifuge, which
is able to carry a load of a litre at a speed of 3000 revolutions
per minute. The supernatant liquid is removed by filtration,

FIG. 2.

Centrifuge—equipped for chemical work. On the right is shown an empty carrier. The
front and back carriers are loaded with rubber-stoppered, glass bottles of 250 c.c. capacity,
such as were shown on the shaking machine. These bottles, which contain the meat and its
aqueous extract, exactly fit the carrier. The fourth carrier is beneath the lid on the left and
is not visible.

and extraction of the insoluble residue is repeated until all the
soluble nitrogen has passed into solution. The combined filtrates
are used for the analysis.

The study of the distribution of the nitrogen has shown that,
during prolonged freezing, the protein of chickens undergoes
a slow and specialized proteolysis; the digestion is similar to
that produced by the action of the enzyme trypsin, as is shown

by the increase in the quantity of amino acid nitrogen; for instance, the light meat of fresh chickens on the average contains 8.44 per cent. of its total nitrogen in the form of amino acids;

FIG. 3.
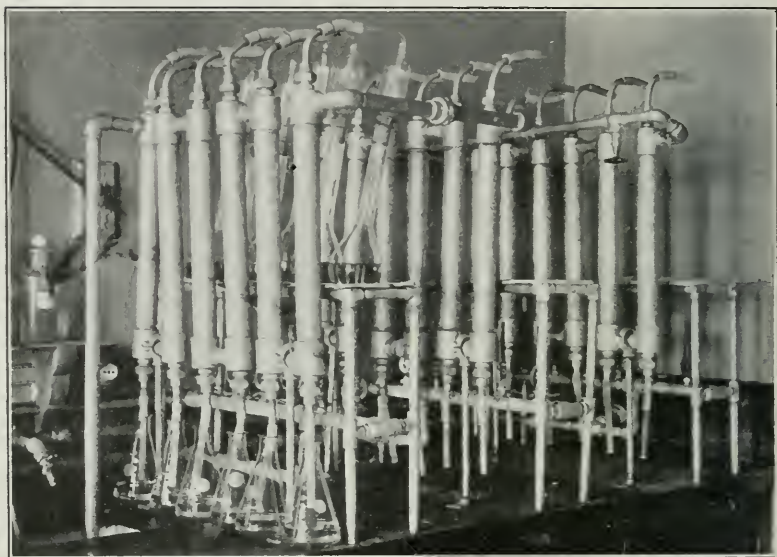
Still for the determination of nitrogen as ammonia. The still is composed of three rows, each of which contains six upright condensers. The cooling water enters at the valve shown in the upper left hand corner, passes through the entire eighteen condensers and empties into the sink at the lower right corner. Each condenser consists of an outer iron jacket, and an inner tube of block tin, to the lower end of which a glass tube of the same diameter is attached by means of rubber tubing. Upon the front row, a distillation has just been carried out. The long-necked, pear-shaped, Kjeldahl flasks, which are used for both digestion and distillation, are connected to the inner tube of the condenser by means of rubber stoppers and safety splash traps (or distilling heads). The joint between trap and tube is made tight by means of rubber tubing. The distillate is caught in Erlenmeyer flasks. Heat for the distillation is supplied by gas burners.

after storage in the frozen state for 4 months, this form of nitrogen has increased and its mean quantity now amounts to 8.95 per cent. of the total nitrogen of the light meat.

FAT ANALYSIS.

In the analysis of the fat, not only have the ordinary constants like iodine, saponification and Hehner numbers and acid value been studied, but the investigation has also included within its scope at times such determinations as phosphorus content,

lactones, aldehydes, acetyl value, etc. Of the interesting changes which occur in the fat of chickens during their transportation and storage, the following examples may be given. If the birds be kept at either ordinary or lower temperatures, the acidity of the fat increases. The mean acid value of the fat of 6 fresh chickens was 0.8, while the mean value of this constant had risen to 2.5 in the fat of twelve birds which had been kept hard frozen for four months.

During storage in the frozen condition the saponification number and Hehner number undergo a change in the same direction at the same time; thus the fat of six fresh chickens gave a mean saponification number 173.5 and a mean Hehner number 82.10, while the fat of twelve chickens of known history hard frozen for four months had a mean saponification number 146.9 and a mean Hehner number 66.27; in other words both constants have undergone a simultaneous decrease. An extensive survey of the literature upon the natural changes occurring in fats and oils has failed to reveal any record of fat decomposition of this type, for an increase in saponification number is usually accompanied by a decrease in Hehner number and vice versa. Hence during the study of the changes in chicken fat *in situ* at temperatures below freezing a new type of fat decomposition has been observed.

NEW METHODS OF ANALYSIS.

The extraction and analysis of fat consumes several days, as does also a complete protein analysis. Therefore in the study of the changes in fat and protein during the transportation and marketing of poultry, it became necessary to devise rapid yet very delicate methods of analysis, in order that several samples might be examined daily. The acidity of the crude fat was found to be an excellent indication of the amount of decomposition in the fat, and the quantity of ammoniacal nitrogen in the flesh was a delicate and accurate measure of the decomposition of the proteins. The crude abdominal fat is ground in a meat chopper; a sample is weighed out in a tared flask and heated on an electric stove with neutral alcohol until the latter boils briskly; the free acids are immediately titrated with standard alkali.

The determination of the ammoniacal nitrogen is based upon the following principles. If meat, magnesium oxide and water

be mixed at room temperature, the ammonia-like compounds will be liberated. If a current of air be drawn through the mixture, then through a known volume of standard acid, these volatile ammonia-like compounds will be removed by the air from the mixture and carried into the acid, which combines with and

FIG. 4.

Determination of ammoniacal nitrogen by aeration. The air is drawn through sulphuric acid in the large flask, passes through an empty flask which serves as a trap, then divides and is drawn through the flasks of which four sets are connected in parallel. In each set there is a generation flask, in which the ammoniacal nitrogen is liberated, then an empty flask which serves as a trap, next a flask containing a known volume of standard acid to absorb the ammonia-like compounds, and lastly another empty flask functioning as a trap. The latter is connected with the vacuum pump by rubber hose and iron pipe.

neutralizes them. At the end of the analysis, the excess of acid is determined and the quantity of ammoniacal nitrogen is calculated. The air current is generated by a vacuum pump driven by an electric motor.

PHYSICAL APPARATUS.

The methods and machinery of physics and physical chemistry find frequent application in the work of this laboratory. The microscope is an indispensable portion of the equipment of the bacteriological and histological laboratory. A special condenser for dark ground illumination produces total reflection at the upper surface of the coverglass of all the light rays save

those which are diffused by the bacteria on the slide, these organisms therefore appear beneath the microscope as intensely illuminated bodies on a dark field. Both the microscope and polarizing microscope are of value to the chemist. The saccharimeter serves for the determination of sugars in the optical way; the Dubuscq colorimeter is used in the colorimetric determination of creatin and creatinin, the spectroscope is utilized in the

FIG. 5.
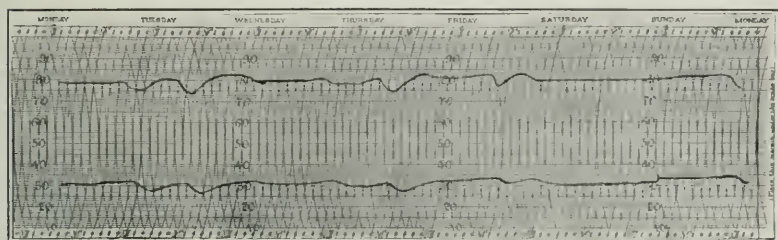
Hygrothermograph record—chill room—mechanical refrigeration. The upper curve is a record of relative humidity, the lower curve of temperature Fahrenheit.

FIG. 6.
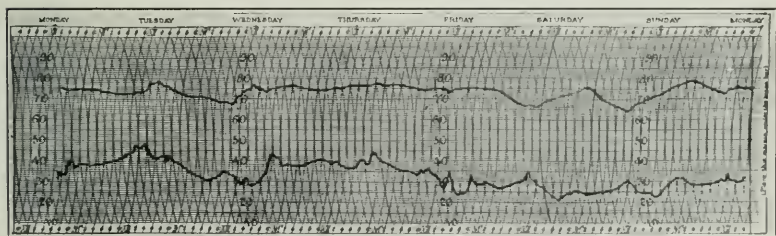
Hygrothermograph record—laboratory. The upper curve is a record of temperature Fahrenheit, the lower curve of relative humidity. The two charts here reproduced are a record of the temperature and the relative humidity of the chill room and of the laboratory for the same week. It will be noticed that in the chill room the two curves, temperature and relative humidity, are practically parallel, while in the labratory the two curves are more or less independent of each other, and occasionally may go in opposite directions at the same time.

study of the absorption spectra of natural coloring matters, and the Abbe and immersion refractometers provide an excellent method for the determination of the index of refraction. The egg-candle is a form of optical apparatus, hitherto considered as of commercial value only, which makes possible a study of the physical condition of the egg in the shell, including the position of the yolk with respect to the white, the motility of the

yolk and the density and opacity of both white and yolk; it also reveals " rots " and " spots."

The temperature of the electric muffle furnace, which is used in the determination of ash, is measured by means of a thermo-electric pyrometer. The thermograph furnishes a permanent record of the temperature of the room, chill room, ice box, cold storage or refrigerator car in which it may be placed. The hygrothermograph provides a means of obtaining a permanent record of both the temperature and the relative humidity. The freezing point of milk has to be determined to the thousandth of a degree Centigrade, therefore recourse is made to the freezing point apparatus of Beckmann.

The eudiometer finds application for measurement of the volume of oxygen liberated from hydrogen peroxide by the enzyme catalase. To reduce the volume of the oxygen to standard conditions, the barometric pressure must be known; therefore, the laboratory is provided with a barometer. By means of the torsion viscosimeter, the viscosity of a liquid may be determined. The Westphal balance is occasionally used for the determination of the specific gravity of liquids, although a pyknometer is usually employed for that purpose. Needless to remark, the laboratory is provided with several balances and a full supply of graduated glassware including burettes, reservoir burettes, pipettes, flasks, a Muter tube for the isolation and study of liquid fatty acids, and several Gottlieb Röse tubes for the quantitative determination of milk fat.

BACTERIOLOGICAL WORK.

Various researches in bacteriology have been carried out. A study has been made of the bacterial content of fresh birds and during marketing, while the relative number of organisms in the wall of the abdominal cavity of drawn and undrawn fowls has become the subject of special investigation. The number of bacteria present in fresh eggs as well as their species, have been determined; and the rate of growth of micro-organisms in milk kept at low temperatures has also been studied.

The investigation of the bacterial content of poultry while hard frozen may be taken as a type of these researches. The technic first had to be developed. Samples of flesh from the pec-

toralis minor muscle were removed from the birds with sterile
instruments and weighed in tared sterile flasks containing frag-
ments of glass. A definite volume of sterile physiological salt
solution was then added and the flask was shaken for 10 minutes,
by which time the meat was disintegrated by the action of the
glass and water. The resulting suspension was plated. Plates

Fig. 7.
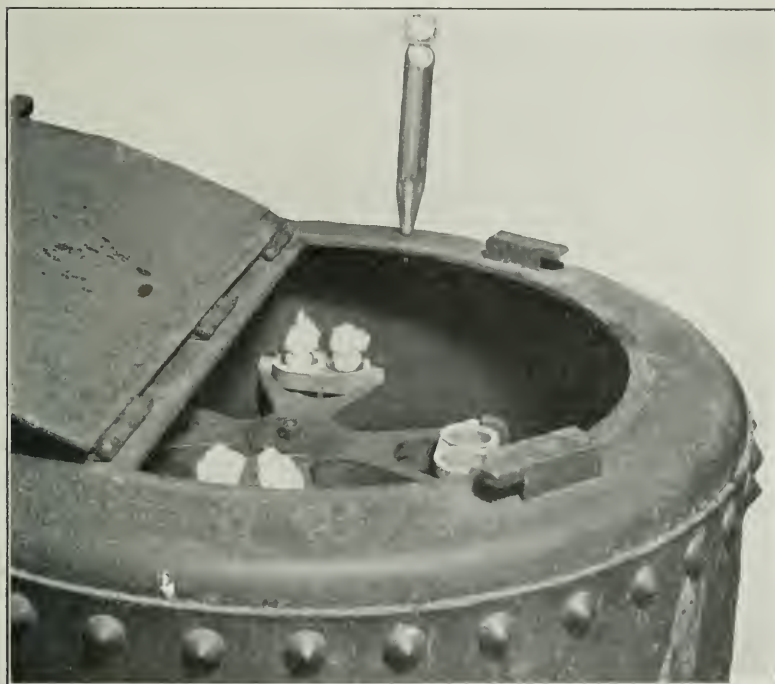
Centrifuge—equipped for bacteriological work. On the right is an empty carrier with
two compartments, each of which holds a pointed, cotton-plugged, glass tube such as is seen
on the top of the centrifuge. The front and back carriers are loaded with such tubes. The
fourth carrier is beneath the lid on the left, and is not visible.

were poured in the usual way to obtain the total number of obli-
gate aërobes (micro-organisms requiring free oxygen for their
development) and facultatives (micro-organisms developing in
either the presence or absence of free oxygen). The total num-
ber of facultatives and obligate anaërobes was ascertained by the
double-plate method of Wright. The latter are micro-organisms

which develop only in the absence of free oxygen. The spore-forming micro-organisms which commonly give rise to putre-faction are able to resist a temperature of 80° C. for 10 minutes; the suspension was therefore subjected to those conditions, then plated by Wright's method to determine the number of these organisms present in the flesh.

Roasting and boiling chickens of known history, both drawn and undrawn were kept hard frozen for four months at a temperature of —10° C. " In every case bacteria were present in the muscles of the breast and thigh, and the walls of the abdomen, though usually the number was small and the great majority of the organisms were of the aërobic type. Very few bacteria resistant to 80° C., were found and not one of those appearing on Petri plates, poured according to Wright's method, proved to be obligate anaërobes, when subjected to further tests. Neither was gas produced, when the suspension of the flesh of the fowls was added to glucose bouillon in fermentation tubes."[1]

Market chickens which had been kept frozen for periods varying between fourteen months and four years were also examined. The fowls which had been hard frozen for fourteen months and seventeen months had a high bacterial content, and the presence of bacteria in their thigh muscles could be demonstrated histologically. In these birds there was noted " a marked tendency toward a relative increase in the number of bacteria developing at 20° C., as compared with those developing at 37° C."[2]

Later studies which have included the investigation of trade methods of preparing poultry for market as well as the fact that a delay in putting the produce into the freezer is often practised by ignorant merchants, would indicate that the findings quoted were due to bad handling before freezing, not to the effects of prolonged freezing itself. It has also been demonstrated, however, that deterioration begun in flesh before subjecting it to low temperatures is not completely checked by cold.

The chickens of known history kept hard frozen for four months showed a tendency toward an increase of the types of organisms which proliferated at 20° C., though it was much less marked.

[1] Premier Congres International du Froid, 1908, ii, 232.
[2] Premier Congres International du Froid, 1908, ii, 240.

Living bacteria were present in chickens kept hard frozen for four years, as was shown by the plating methods, although they were not revealed by histological analysis. The proportion of these organisms which developed when the plates were incubated at 20° C. was large; either the organisms developing at higher temperatures had been destroyed by the long exposure to low temperatures, or else the forms able to resist cold had increased. The birds which were hard frozen for four years, as well as those frozen for two years, contained more organisms able to resist a temperature at 80° C., than did the fowls which were kept for shorter periods.

These researches prove "that organisms can survive for long periods at temperatures far below the congealing point and that growth is prompt and vigorous when a suitable environment is provided."

Later researches have shown that even if a chicken be kept in a chill room at a temperature of about 32° F. for twenty-four hours after killing, bacteria will then be present in the flesh adjacent to the bones and in the muscles directly beneath the skin. A study of the penetration of muscle by organisms is now in progress.

HISTOLOGICAL STUDIES.

A histological study of chicken muscle has revealed a progressive change in the microscopic structure during storage in the frozen state. A longitudinal section of the muscle of fresh chicken is characterized by a wavy appearance; the line of demarcation between the fibres is very faint and the cross markings though visible are not especially striking. After storage for even one month, histological changes have occurred which become more pronounced as the period of storage increases. The wavy appearance of the longitudinal section disappears; the cross markings become brighter; the fibres pull apart, and material resembling coagulated foam appears between both the fibres and the bundles of fibres. After storage for three months this pulling apart of the individual fibres reaches such a stage that capillaries, which run parallel to the fibres, may be traced for long distances by means of the nuclei of their walls and the blood corpuscles within them. At the end of five months, some of the fibres have changed to a homogenous material; a breaking of

the sarcolemma or muscle sheath may occur, accompanied by an exudation of this homogenous material. The exudate is a fine granular precipitate, containing here and there displaced nuclei and blood-corpuscles and shreds of blood-vessels. Transverse cracks appear in the fibres after storage for five months; at ten months the fibre is broken into very short transverse segments; and at twelve months the tissue consists of short pieces of fibres dislodged from their normal positions and in fragments. With age, the brittleness of the muscle increases. These changes suggest autodigestion.

During decomposition at ordinary temperatures, the histological changes differ greatly from those occurring during prolonged freezing. Even when putrefaction is far advanced, though a pulling apart of the individual fibres may take place to a certain extent (due probably to dessication), yet neither interfibre material nor exudate has been found between them. During putrefaction the cross markings have not been intensified, and short, broken segments are far less frequent than in frozen birds. While certain fibres may be annihilated and thus give rise to empty spaces, during decomposition at ordinary temperatures, yet the former position of the fibre is never indicated by a homogenous mass such as occurs in hard frozen fowls.

Decomposition at ordinary temperatures gives rise to an odor of putrefaction, while storage in the frozen state leads to the development of a biting odor, recalling that of a mild rancidity. This odor is probably located in the fat.

ZYMOCHEMICAL INVESTIGATIONS.

Since enzymes play a prominent part in the natural changes which occur in foodstuffs, certain researches have been carried out in the field of zymochemistry. Thus a study of the occurrence of lipase in the crude fat of chickens is now in progress. the enzymes of milk. *e.g.*, catalase, oxidase and peroxidase, have also been studied.

[NOTE.—Part II, "The Scientific Study of the Handling of Perishable Foodstuffs," and Part III, "Select Methods of Analysis" will appear in early issues of the JOURNAL.]

THE MATERIALS OF PAINT MANUFACTURE.*

BY

G. B. HECKEL.

DURING recent years we have become somewhat familiar with the term " Scientifically Prepared Paint," and have heard or read some controversy over the propriety of the term. I hope to show before I finish that the term is justified and that prepared paint is not only a product of science and civilization, but that it is also a result of progress and evolution, as much as any other modern product.

An English writer has said of paint making that it was first an art, then a trick, but that now it has become a science. I have here a relic of the earliest known American Paint Makers— probably the same people who built the mysterious mounds of the Mississippi Valley. It is an axe or hatchet of hematite, and if properly crushed and ground would make a good grade of iron oxide. It was found in a tunnel uncovered at Lesley, Missouri, by modern miners who are still taking oxide from the same vein. Iron oxide was one of the pigments known to the aboriginal. He reduced the native hematite to powder, mixed it with oil, grease, mucilage or gums and applied it as a heraldic decoration to his face or wigwam, or used it in the crude decoration of his household utensils.

The history of all races in the use of paint is practically the same. The first pigments used are the natural earth colors or simple vegetable dyes. They are devoted to personal decoration—commonly heraldic—and later their use is extended to other decorative purposes. It is only in a higher stage of development and civilization that the protective value of paint is recognized. This evolution is the natural accompaniment of change from the nomadic state, where dwellings are temporary, to the fixed life of civilized society.

Let us consider a typical high grade paint formula. It contains the following ingredients:

ANALYSIS OF PEA GREEN.

(United States Standard Measure.)

	PER CENT.
Pigment by weight	48.00
Thinner by weight	52.00
	100.00

Thinner is composed of:

Linseed oil	85.00
Asphaltum spirits	3.00
Turpentine	1.00
China wood oil	2.00
Japan dryer	9.00
	100.00

Composition of pigment:

Hydrocarbonate of lead	15.00
Basic sulphate (white lead)	20.00
Zinc oxide	44.00
Silicate of magnesia (asbestine)	3.00
Calcium carbonate	2.00
Barium sulphate (blanc fixe)	10.00
Silicate of alumina	3.00
Lead chromate	2.30
Ferro-ferri cyanide of iron	.70
	100.00

Coloring is composed of:

Pure chrome green	100.00

Composition of Japan dryer:

Kauri gum	1.67
Lead oxide	8.45
Black oxide of manganese	2.00
Linseed oil	26.44
Turpentine	61.44
	100.00

Besides these ingredients that are mentioned on the label, we may also notice that the container is made of tin plate; that the can is soldered; that the labels are printed with two colors of printing ink on white paper, and pasted on the can. Finally we may recall

that such cans are packed with sawdust in wooden boxes nailed together with steel wire nails. Keeping in view the finished can and its contents, I think you will catch my drift, when I say that all science and all civilization have gone to the making of the can of paint bearing this label and that without science and civilization it would be unthinkable.

Let us consider briefly the ingredients, one by one: The first is linseed oil, a product of the flax plant, *Linum usitatissimum*. The flax plant was not first cultivated by man for the seed or its oil. Its earliest use was for the making of linen cloth. The great masters of early European art knew nothing of linseed oil, and the first use of the seed was medicinal. To-day in the United States alone over twenty-five million bushels of flaxseed are consumed annually in the manufacture of linseed oil, the great bulk of which goes to the production of paint and varnish. To produce so much seed requires from two million to two and one-half million acres of soil. Its cultivation requires many farmers and laborers, much special machinery; its storage and transportation utilizes elevators, railroads, steamships; its use for oil-making requires elaborate plants, much special machinery; and the treatment of the oil for its various uses involves chemistry and the mechanical arts. Moreover the oil-growing flax is itself a product of agricultural science, which is to-day more ardently pursued by plant specialists than ever before. The proper preparation and use of linseed oil involves the results of profound study and investigation, which to-day are still far from completion.

In the manufacture of linseed oil the flaxseed, cleaned from foreign seed and other impurities, is first ground in a series of roller mills. The resultant meal is treated in a special heater with live steam to break up the oil cells. This hot meal is then pressed into the desired form and size for the oil presses, in a cake former; and a number of those cakes are stacked, one above the other, in camel's hair or other fabric cloths, between the plates of a specially devised hydraulic press. An enormous pressure is applied and the expressed oil is filtered and collected in settling tanks, where the moisture, plant mucilage, etc., settle to the bottom, while the clear oil collects on top and is drawn off and sold as raw linseed oil.

Linseed oil is a very complex organic chemical compound, but consists essentially of the glycerides of a number of fatty

acids. Of these the most important in connection with our subject are the glycerides of linolic and linoleic acids, to which the oil owes its characteristic property of absorbing oxygen and thereby becoming converted to linoxin—the characteristic rubberlike product of " dried " linseed oil.

The presence of certain metals facilitates this process, and these metals are incorporated with the oil by heating their compounds with the raw oil. Recent investigations indicate that the only two metals practically effective for this purpose are lead and manganese, and consequently advanced manufacturers have generally abandoned the use of other compounds.

It will be noted that the liquid portion of our paint contains 85 per cent. of linseed oil. The fact is significant, for while linseed oil leaves something to be desired when we contemplate the ideal paint, it is nevertheless the most satisfactory paint oil for general use known to us up to the present time.

The remaining fixed oil in our formula is China wood oil, of which only 2 per cent. are present. China wood oil is comparatively a recent addition to the raw materials of paint and varnish manufacture. It is expressed from a nut grown on a tree (*Aleurites cordata*) indigenous to the Yangtze Valley, in China. The variety producing the oil nut is known to the Chinese as *ying tzu tung* (apple fruit Tung) and the tree is cultivated by the Chinese farmer for its oil. It grows to a height of about 25 feet, bears large green leaves, small pinkish flowers and large green fruit somewhat resembling an apple. The seeds are large and poisonous, and from them the oil is obtained. The machinery used is primitive, consisting essentially of a wooden press operated by wedges. The oil is traded, along with other agricultural products, to merchants at Hankow, Fatchau and Canton. It has been used in China for ages, much for the same purposes as linseed oil is used in this country, and it is said that the extracted seed residues are the raw material for the manufacture of India ink.

But little is as yet known generally regarding the chemistry of this oil. It has drying properties similar to a certain extent to those of linseed oil, and the rate of hardening is accelerated by the same agencies that promote the oxidation of the more familiar oil. The chemical process appears, however, to differ, since while

linseed oil hardens progressively from the surface inward, China wood oil seems to harden or set simultaneously throughout. This peculiarity led to rather expensive disasters in the earlier attempts to utilize the oil in this country. The drying salts are incorporated in practice at a comparatively low temperature; but in these earlier experiments the oil was treated at the temperature common in the treatment of linseed oil, with the result that the entire batch suddenly thickened to the consistency of rubber, in the kettle.

While the use of this oil is still the subject of experiment, it has established for itself an important place in the varnish industry, and is making rapid strides in the paint industry. It is believed that it adds a certain desirable solidity to the paint film and is especially valuable when rosin or resinates are present in the Japan dryers.

The two volatile ingredients of our formula are asphaltum spirits and turpentine. Asphaltum spirits is one of the lighter products of petroleums having an asphaltum base. It corresponds to the benzine which is produced from petroleums with a paraffin base. The chemistry of these hydrocarbons, while interesting, plays no part in the chemical structure of the paint film, since their office is purely mechanical and they disappear completely in the drying of the paint. As is well known, the petroleums found in some localities yield on distillation at high temperatures, residues containing paraffin, while similar oils from other localities yield asphaltums as residues. The best known petroleums of the latter class are those produced in Texas, California, and the Island of Borneo. Petroleums are distilled by fractionating, the products passing over at the lower temperatures being classified progressively as petroleum ethers, naphthas and gasolenes, and benzines. At still higher temperatures the illuminating oils pass over, followed by the lubricating oils. Asphaltum spirit is the benzine of the asphaltum petroleums. It boils at a higher temperature than the corresponding paraffin product, has a higher specific gravity and is, on many accounts, far preferable as a volatile ingredient of paints. I personally believe that the formula before us is mechanically improved by the presence of this material and I am convinced that it is in no way injured by it.

Turpentine is the essential oil of certain pines, principally

Pinus Australis, growing over large areas of our Southern States. It is distilled in a current of live steam from the sap of this tree, the residue being rosin. The industry, owing to the character of the labor available in the pine districts, is crude and wasteful both to the timber involved and to the product, though more conservative methods are coming into use through the efforts of the United States Department of Agriculture.

The negro workman in a turpentine orchard cuts a so-called " box " on one side of the tree, in which the sap collects, and from which it is from time to time dipped and carried to the still. As the flow of sap decreases, the bark is removed and the wood scarified higher and higher above the " box." In the larger trees several boxes are cut at different points on the circumference, weakening and in time killing the tree. The crude sap or gum is charged into a still with water, and on heating, the volatile turpentine passes with the steam to the worm condenser. The turpentine is decanted from the condensed steam on which it floats.

Turpentine in paint probably acts in two ways: first, as a volatile thinner, of which the effect is purely mechanical; and secondly, as a conveyer of oxygen, perhaps catalytically. At any rate it was the conclusion of a French technical commission who investigated the subject, that turpentine hastens the drying of paint to an extent not accounted for by its volatility.

The principal turpentine forests of to-day are located in Florida, southern Georgia and Louisiana, the immense forests that formerly covered vast areas in North and South Carolina and northern Georgia having been largely destroyed by the wasteful methods in vogue. Another form of turpentine has appeared in the market during comparatively recent years. It is familiarly known as wood turpentine, being produced, by various methods of distillation, from pine wood wastes. When properly prepared and purified, there appears to be no practical difference in its properties as a paint vehicle from those of sap turpentine.

The remaining liquid ingredient of our formula is Japan dryer. This consists essentially of the linoleates of lead and manganese, with a small percentage of Kauri gum. It is prepared by boiling linseed oil with the proper percentages of compounds of manganese and of lead adding thereto a certain quantity of melted Kauri gum, and reducing the product while warm, with turpentine, benzine or a mixture of the two. The lead compound used

in this dryer is red lead and the manganese compound is the black oxide, while the reducing agent is turpentine and Texas benzine—asphaltum spirit.

The manufacture of red lead leads us at once into the mining regions of the West, where in some districts lead is produced from practically pure ores, while in others it must be separated from its commingled silver, zinc, etc.

For the manufacture of the so-called Dutch Process white lead it is necessary to have the metal free from silver, manganese and iron; but for the manufacture of the ordinary oxides purity is not so important. The metallic lead comes from the smelter in the form of pigs, which are melted in a low flat oven in which the lead spreads out in a thin layer and is mechanically worked so as to expose continually fresh surfaces to the action of the air. The product is the monoxide of lead—massicot. This oxide is ground with water to remove metallic particles, which are returned to the furnace, while the oxide is collected in settling tanks. If the temperature in the furnace rises too high it becomes litharge—crystalline lead monoxide—which cannot be further oxidized.

The amorphous monoxide, being further treated in the same or a similar oven, at a low red heat, with free access of air and constant stirring, gradually takes up more oxygen and is converted into red lead—a combination of the monoxide and the dioxide, in the proportion of about two parts of the former to one of the latter. The product is usually stated as having the formula Pb_3O_4, but red lead is, as noted, a mixture of oxides rather than a definite chemical compound.

The black oxide of manganese, known to mineralogists as Pyrolusite, is a natural product, of which the principal sources of supply are in the Caucasus Mountains, in the Hartz Mountains and elsewhere. Chemically it is the dioxide of the metal manganese. The miners are the wild mountaineers of eastern Europe, and the mineral before it reaches America, passes through southern Russia, the Black Sea, the Dardanelles, the Mediterranean and so across the Atlantic. For the use of the varnish and dryer manufacturer it is subjected to mechanical purification.

These two metallic oxides readily replace the glycerin in linseed oil at moderate temperatures, forming oleates and linoleates, while the glycerin is decomposed and driven off.

The addition of a resin—in this case Kauri gum—at a moderately high temperature also probably induces the formation of resin acid compounds of the metals.

The driers made with lead and with manganese have sharply distinguished properties, of which advantage is taken by the well-informed manufacturer, who knows that certain proportions of the two yield better average results than either alone. He also carefully calculates the percentage of the metal in the drier to the oil to be oxidized. Kauri gum, besides helping the quality of the japan, has also been shown by experience to serve a useful purpose in paints containing high percentages of zinc oxide. It is found only in New Zealand where ancient forests of the tree which produced it—the *Dammara Australis* and other varieties of Dammara—have been buried for ages in the earth. It is mined systematically by trenching and is cleaned, sorted, and classified by hand.

We have now briefly covered the liquid portion of our formula and in the course of our survey have gone to North Dakota for flaxseed, to Florida for turpentine, to Texas for benzine, to China for wood oil, to Colorado and Montana for lead, to the Caucasus for manganese, and to New Zealand for Kauri gum. Even at this point we may begin to see that for this ordinary can of mixed paint the manufacturer has been under the necessity of calling upon many industries, several races and different quarters of the globe. It is no less so with the remaining items of our formula and the package in which it is sold. Lead hydrocarbonate is the first named of the solid ingredients. In this case it happens to be Dutch Process White Lead.

Lead hydrocarbonate or basic lead carbonate is a molecular combination of the hydroxide and the carbonate of lead in about the proportion of two parts of the latter to one of the former, though these proportions are only approximated in actual practice. The accepted formula, however, is $2 PbCO_3, PbH_2O_2$. Of the three processes used to any extent for the manufacture of this product, two employ acetic acid in an intermediary step of the chain of reactions, while the third dispenses with it.

The Old Dutch Process, so called—though it has undergone great improvement in English and American practice—starts with desilverized lead pigs, known in the trade as " soft lead." These are melted, and the molten lead is distributed on shallow

moulds on an endless chain belt. The moulds give the metal the form of a flat circular grating or buckle about $^3/_{16}$ inch thick by 5 inches in diameter. These buckles are packed into earthenware pots, having at their bottoms shallow wells containing each about half a pint of vinegar or dilute acetic acid. These pots are arranged in tiers between layers of spent tan bark, where they are allowed to remain undisturbed for about 130 days. By the fermentation of the tan bark heat is generated and carbonic acid liberated. The heat vaporizes the acetic acid, which attacks the lead, coating the buckles with basic lead acetate. This in turn is attacked by the carbonic acid, producing the basic carbonate and liberating neutral lead acetate, which attacks the metallic lead beneath, producing again the basic acetate. The process thus continues progressively until most of the buckle has been altered to the basic carbonate. The buckles being removed from the pots are subjected to mechanical treatment which separates the corroded from the uncorroded portions. The white lead being ground, washed, floated and dried, enters commerce as dry white lead. The special characteristics of corroded white lead are its excellent working properties and low oil consumption, giving a high degree of opacity or color-body in the finished paint.

The second process, commonly known as the " quick process," also starts with desilverized pig lead. This is melted and finely comminuted in a steam blast, and the granulated product is charged into large, slowly revolving wooden drums, where after being moistened with dilute acetic acid it is subjected for some hours to the action of purified carbonic acid gas from burning coke. The slow revolution of the drums insures the exposure of the entire mass to the action of the gas. The chain of chemical processes involved is probably identical with those described for the Old Dutch Process. The mechanical treatment of the crude corroded product is essentially the same. The finished product is more uniform in the size of particle than Dutch Process Lead and finer in texture. This involves a larger oil consumption and a consequent decrease in opacity or color body of the completed paint.

The third process, known as the Mild process, because of the fact that acetic acid is not used, is applicable to pig lead of any description. In this process, also, the metallic lead is finely comminuted in a steam blast. In both this and the preceding

process there is a preliminary surface hydration produced by the action of the water vapor on the lead particles. The finer particles are charged into revolving drums containing water and there subjected to the action of air under low pressure for several hours. The lead is thereby converted into the basic hydroxide. This hydroxide is then subjected in similar drums to the action of purified carbonic acid gas for the requisite time, until the conversion to the basic carbonate has been carried to the proper point. The product is extremely white, uniform and pure, requiring only floating and drying to fit it for use.

The second pigment of our formula is Basic Lead Sulphate or Sublimed White Lead. As indicated by its title, this is a sublimation product, and is produced directly from the native ores of Missouri—lead sulphide—by oxidation at a high temperature in a current of air. The comminuted ore is charged in a special furnace with coal or other fuel and is subjected to a hot-air blast. The sulphide takes up oxygen, volatilizes and is carried through a series of cooling flues to fabric bags, in which it is collected. This is the process in outline, though not in detail. The reaction involved is simple: the lead sulphide, PbS, takes up four equivalents of oxygen from the air, being converted into lead sulphate, $PbSO_4$. At the same time it is also claimed, with much probability, that there is formed a certain proportion of the basic lead sulphate, $Pb_3S_2O_9$. At any rate analysis always yields an excess of oxygen, which is usually calculated to lead oxide, the percentage of which ranges from fourteen to twenty. The product, furthermore, always contains a small percentage (five to six) of zinc oxide, which comes from the zinc sulphide associated with the ores used. It may be said in passing that lead sulphate, chemically produced, is a very unsatisfactory pigment, exhibiting none of the characteristics of sublimed white lead. The latter, on the other hand, is extremely useful, and in certain combinations has come to be regarded as almost indispensable. The particles of this pigment are extremely fine and uniform, approaching the particles of zinc oxide in this respect. As a pigment, it stands between corroded white lead and zinc oxide in most of its characteristics. Paints made with it chalk more freely than paints made with the former, but on the other hand, they retain their color better, and do not " check " so freely. Proper

combination with zinc oxide restrains the characteristic chalking, while the hardening peculiar to zinc is in turn restrained.

Our third pigment is Zinc Oxide. Zinc is peculiar in that it is the only metal in common use produced by distillation. It is volatile at an easily attainable temperature and advantage is taken of this fact in recovering the metal from its ores. The hot metallic vapor is also readily oxidizable, and if exposed to the air, will take fire, burning with a green flame to zinc oxide.

The oxide is produced by two different processes. One, known as the French Process, taking advantage of the fact just mentioned, volatilizes the metal in a current of air, and collects the resultant oxide in closed chambers.

In the other process, known as the American process, the oxide is produced directly from the ores. On the nature of the ore used depend the individual characteristics of the resultant oxide.

In this process the comminuted ores are mixed with powdered anthracite and charged into closed furnaces having perforated grate bars. Combustion is started in the anthracite and a blast of air is forced through the perforations in the grate. The heat smelts the ore and volatilizes the zinc, and the metallic vapors promptly combine with the oxygen of the blast, producing zinc oxide. This oxide is carried through a series of cooling flues and collected in fabric bags. The particular oxide used in this formula is made from New Jersey ore, and on that account is of some interest. This ore is unique in that it occurs in commercially available quantities, nowhere else in the world. It is known as Franklinite, and consists of the oxides of zinc, manganese and iron in molecular proportions—crystallizing as a true mineral. It is closely associated in the vein with other compounds of zinc—the anhydrous silicate, the oxide, etc. A peculiarity of the product is that the oxide recovered is practically free from impurities, averaging over 99 per cent. pure oxide. The oxides produced from other available ores usually contain from 5 to 15 per cent. of lead sulphate, due to the presence of lead sulphide in the vein.

The characteristics of zinc oxide are too well known to require extended comment. It is the finest and whitest of all white pigments; is chemically quite stable, the only chemical changes possible in practice being to the sulphide or to the carbonate, which are also white. It is bulky and hence carries a high percentage of

oil in the finished paint; and finally when properly used is very durable. One is fairly safe in saying that if Oxide of Zinc had not been introduced as a pigment, there would have been no prepared paint. It was produced as a commercially available pigment, in answer to a demand that had been voiced in Europe from the closing years of the Eighteenth Century, to the time of its introduction about the middle of the nineteenth. This demand for a non-poisonous white pigment finally received a satisfactory response from a contracting painter of Paris, Le Claire, who was also celebrated as a philanthropist and is known to this day as " the father of profit sharing." Practically every great chemist of Europe from Lavoisier to Faraday had his try at the problem.

Our next pigment is the silicate of magnesium, in the form of asbestine. This product comes principally from Canada. Its usefulness in the paint formula depends entirely upon its physical form, which is acicular or rod-like. Its office in the paint film has been compared to that of the hair in plaster or the rods in reinforced concrete. It is without special value either for opacity or protection, but aids in holding the materials in suspension and very probablly also in resisting stresses in the dried paint film.

Our fifth solid ingredient is Calcium Carbonate—in this case a natural product from Missouri—a dolomitic crystalline rock, finely ground for the purpose. Calcium carbonate, as used in paint manufacture, comes to us in two forms. Whiting, Paris White, etc., are the pulverized and floated chalk supplied principally by the chalk cliffs around Dover, England; the calcareous skeletons of innumerable diatoms that once populated the waters of an ocean covering that portion of the earth, ages before the advent of man; while the product used in this formula is from a similar geological source, but in succeeding epochs subjected to heat and pressure, which gave it a crystalline structure. As a rule manufacturers in selecting from these two forms are governed by the conditions: if the remaining inert pigments are crystalline, Paris White is selected: if not, then the so-called mineral primer is preferred.

Either will neutralize any free acid in the paint, but the mineral primer will in addition give the " tooth " which is thought desirable in the manual work of painting. The only other crystalline pigment in our formula is the asbestine, so mineral primer rather than a form of chalk has been selected for this formula.

Barium Sulphate is the next on our list, and is used in the form of the chemical precipitate—blanc fixe. Personally, I should have preferred the natural crystalline form, barytes, in this case, but that is a matter of detail. The sulphate of barium in the form of barytes is a natural, crystalline product, which retains its crystalline form, no matter how finely comminuted.

It is found associated with lead, zinc and other ores in most mineral regions. That used in the United States, however, comes principally from Missouri and the Alleghenies in central Virginia, Missouri furnishing the larger proportion. There its production is in the hands of farmers who collect and cart it to the railroads in the fall and winter, to be manufactured into pigment at St. Louis and neighboring points. In the Allegheny regions the mineral is procured by mining.

Blanc fixe is produced by transforming the natural product into a soluble compound and precipitating it from dilute solution with sulphuric acid or a soluble sulphate. The product is chemically identical with barytes, but physically very different, being very finely divided and amorphous.

Silicate of alumina is the next ingredient of our white base. Technically it is a washed and floated China clay, naturally produced by the disintegration of certain feldspars, the soluble potash salts having been washed away. The percentage here used is small, but it has a physical influence on the suspension of the other pigments, in the brushing qualities of the paint and on the quality of the paint film.

The remaining ingredients of our formula are the colors required to produce the desired tint. They have no influence on the quality of the paint. The yellow in this combination is lead chromate—chrome yellow. It is produced by the reaction of a soluble chromium salt, usually sodium bichromate, on a soluble lead salt, usually lead nitrate, both in solution. The neutral chromate of lead, $PbCrO_4$, being insoluble, is precipitated. The production of this familiar pigment again takes us far afield. The chromium used in making the chromates is obtained from an ore of iron known as chromite. It is a chromate of iron, having the composition $FeCr_2O_4$. It is found in small quantities in Pennsylvania, Maryland, California and elsewhere in the United States, but the main sources of supply are Asia Minor and New Zealand. Large quantities of these ores are imported into Eng-

land, Germany and the United States for the sole purpose of manufacturing the chromium salts of potassium and sodium. The process is intricate and difficult, so that the manufacturers are few in number. There is also some demand for the mineral in the manufacture of special steels.

The remaining pigment is Prussian Blue—the potassio-ferro-ferri-cyanide of iron. This material brings us once more into the field of organic chemistry, the non-metallic component of the blue being cyanogen, which is most familiarly known as a component of hydrocyanic or prussic acid and the cyanides of potassium, etc. The chemical composition of the color is indicated by the formula, $K_2Fe_22FeC_6N_6$.

The cyanides are obtained from animal wastes containing carbon and nitrogen, such as dried blood, leather paring, hoofs, horns, etc. These are calcined with an alkali and the ash lixivated with water, and from this liquor cyanides of the alkali metal can be recovered, or the blue may be directly obtained by precipitating with ferrous sulphate (copperas). In practice, in the manufacture of chrome green as used for tinting in the present instance, the colors are precipitated simultaneously from solution, either with or on the base, which in this case is the blanc fixe shown in the formula.

We have now glanced hastily at the characteristics of our several ingredients, but they are still only raw materials and require a long series of mechanical operations before our can of paint will be ready for use, not to mention the detailed work of the chemist to determine the quality of the materials themselves.

A modern paint factory is a complicated institution, and in the limits of such a paper as this can only be touched upon briefly and hastily. Power in the most modern plants is generated at a central point and is distributed to the units in the form of electrical energy. As a rule the raw materials are elevated to the highest point in the plant, so that the product, in its several steps towards completion, may fall by gravity from each point to the next in the process.

The dry pigments are ground separately to the form of a paste with linseed oil. The various components of the white base are then thoroughly incorporated with more oil, the whole is then mixed with the rest of the oil and the remaining thinners in a mechanical agitator, the tinting colors being added either

here or at the preceding step, and the exact tint is attained by addition on the judgment of the expert tinter. The finished paint is measured mechanically into tin cans, which are also soldered and labelled by machinery, and finally these cans are packed in cases holding a given number and guarded from injury by sawdust, placed between them. The boxes are then nailed shut, marked and shipped to the distributors. This is the mechanical routine in the barest outline; but we may observe that it involves the use of building materials, fuel, copper wire, tinplate, paper, printing-ink, paste, box lumber, sawdust, wire nails, etc.

The manufacture of tinplate is an important industry in itself, involving a branch of the steel industry in the production of the plates for this use. These plates are cleaned by chemical means, heated, and coated with metallic tin by dipping in a bath of the molten metal. To obtain the tin for this use we must again go to distant regions. Tin ores are found in small quantities in various parts of the United States. I have in my own collection interesting specimens from South Dakota, West Virginia and Alaska; but so far no commercially available quantities have been found in these localities.

Cornwall, from the time when the Phœnicians traded to Britain for tin to the days of the first McKinley tariff, was the chief source of the world's tin supply. But the drain finally told on the natural resources, and the bulk of the tin consumed to-day comes from the Straits of Malacca and from Australasia. In the former locality it is recovered by placer mining methods and in the latter by the usual methods of underground mining. The ore is found in two forms, as the oxide, Cassiterite, and as the sulphide, Stannite, in which latter form it is associated with iron. The smelting of the ore for the metal is done principally in England and other parts of Europe.

The paper for our label is a product of sulphite wood pulp as is most of the paper used for advertising paint. We need not enter farther into this subject except to note that our industry involves also the paper manufacturing industry.

Similarly we may note in passing that the printing ink manufacturer and through him the lampblack manufacturer, the color maker and the varnish manufacturer are involved.

Finally, in the consumption of paste, we return once more to the farmer on whom we called in the first instance for our linseed

oil. In order that I may not be suspected of straining for effect when I include these items in the enumeration, it will be interesting to know that in the year 1909 one paint manufacturer reports to me the following items:

Paper for labels...........................	$ 2,520.00
Paper for advertising matter................	18,840.00
Black and colored ink for labels and advertising matter	2,736.00
Solder for soldering tin cans (of which again tin is a constituent).....................	125,227 pounds
Output of colored samples..................	33,236,542 pieces

For 1910 these figures should all be increased by about 20 per cent.

Adhesion of Electro-deposited Silver to German Silver Basis Metal. A. McWilliam and W. R. Barclay. (*Inst. of Metals,* Jan. 1911.)—The peeling of the silver deposit in high grade plated goods when subjected to severe conditions of wear was investigated. Heavy deposits of silver were made, under similar conditions, on various grades of German silver, and the finished articles subjected to a cold bending test. The thicker the silver deposit was, the greater was its tendency to strip off under the strain. The so-called higher grades of basis metal, containing over 14 per cent. of nickel, were found to be of doubtful utility from this point of view, the deposits were much more adherent on the lower grade alloys. This view was confirmed by microscopic examination; so that it seems advisable to avoid too high a percentage of nickel in the basis metal for high grade electroplate which has to endure rough usage. Although these alloys poor in nickel are neither so white nor so strong as the richer alloys, the color is of small importance when there is a heavy deposit of silver, and sufficient strength can be attained by proper mechanical and thermal treatment of the alloys.

Silver Finish on Aluminum. Dr. Robert Grimshaw. (*Metal Ind.,* ix, 9.)—To bring out the color to the fullest degree dip the article in a solution of sodium hydroxide at a temperature of 110° F. to 125° F., rinse in water, and carefully brush with a brass wire brush, keeping the article moist with a solution of soap-root and water. Again dip in the soda solution, rinse with water, re-dip in the soda, rinse again with water, then dip in a solution of three parts nitric acid with three parts sulphuric acid, and finally rinse in water. Then dry the article in sawdust free from resin (bass wood is best) and lastly burnish.

FRANKLIN INSTITUTE

Additions to membership since last report, 2.

Joseph S. Hepburn, A.M., M.S., presented the paper of the evening, entitled "The Handling, Transportation, and Storage of Perishable Food-stuffs. A review of the Work of the U. S. Food Research Laboratory."

An outline of the work of the laboratory was given from its establishment several years ago to the present time. The apparatus and equipment first installed and those now in use were described in detail, as well as the chemical, bacteriological, and histological investigations made in connection with the study of poultry.

The effect of low temperatures and storage on the tissues and muscles of poultry were shown by means of photomicrographic slides. Numerous lantern slides illustrating the best methods of killing and preparing poultry for the market, the most approved manner of packing and shipping, and recent practice in cold storage, were exhibited.

The thanks of the meeting were extended to the speaker. Adjourned.

R. B. OWENS,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

The following reports were presented for final action:

No. 2455.—Hardinge Conical Ball and Pebble Mill. Certificate of Merit. Adopted.

No. 2458.—Colby Electric Furnace for Melting Metals. Scott award. Adopted.

No. 2479.—Behrend High Speed Electric Generators. Scott award. Adopted.

No. 2501.—Wolf Liquid Gas Apparatus and Process. Scott award. Adopted.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Physics.—The Stated Meeting of the Section was held in the Hall of the Institute on Thursday, May 4, 1911, at 8 P.M., with Dr. E. Goldsmith in the Chair. Forty-seven members and visitors were present. The minutes of the previous meeting were read and approved.

Dr. Robt. H. Bradbury of the Southern High and Manual Training High School of Philadelphia presented a communication on "The Teaching of Elementary Chemistry" in which he discussed the two classes of text-books on elementary chemistry—the "conventional" and the "Nature-study" types. He drew the conclusion that a proper combination of the two types in a single text-book is the ideal plan. Dr. Bradbury recommended that the element sulphur and its compounds be made the subject of the first lessons in elementary chemistry, also that laboratory exercises in this branch of the science be carried out by the student as far as possible in a quantitative manner. The lecture was illustrated with experiments.

Dr. Goldsmith, Dr. Keller and Dr. Bradbury participated in the discussion. A vote of thanks was tendered Dr. Bradbury, and, on motion duly seconded, the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Mechanical and Engineering Section.—A meeting of the Section was held on Thursday evening, May 11, 1911, at 8 o'clock, President Walton Clark, Temporary Chairman. Present 75 members and visitors. The minutes of the previous meeting were read and approved.

The paper of the evening entitled "Metering Steam and Gas" was read by Prof. Carl C. Thomas of the University of Wisconsin, Madison, Wis. The flow of fluids and gases in pipes was first given consideration. Extracts from the papers of Pole, dated 1851, were presented and reference was made to the formulæ of Unwin Oliphant Coxe and Lowe. The mechanisms of various meters for gas. natural gas and compressed air were described and illustrated by numerous lantern slides.

A discussion followed the reading of the paper in which Messrs. Gartley, Crisfield, Leeds, Ledoux and the Chairman participated. The thanks of the meeting were extended to the Speaker. Adjourned.

ALFRED RIGLING,
Acting Secretary.

Mechanical and Engineering Section.—A meeting of the Section was held on Thursday evening, May 18, 1911, at 8 o'clock. Dr. E. Goldsmith, Temporary Chairman. Present, 80 members and visitors. The minutes of the previous meeting were read and approved.

Mr. Wilfred Lewis of Philadelphia presented the communication of the evening on "Machine Molding." Brief mention was made of the early patents on the subject beginning with one for a machine for molding screws issued over a century ago. Lantern views of various types of molding and jarring machines were shown and described. Hand and power molding was compared and it was shown by time cards that machine molding requires one half the time of hand molding.

The subject was discussed by Messrs. Stratton, Thorne, the Chairman and the Speaker. On motion, duly seconded, the thanks of the meeting were extended to Mr. Lewis. Adjourned.

ALFRED RIGLING,
Acting Secretary.

MEMBERSHIP NOTES.

Election to Membership.

RESIDENT.

MR. HAROLD C. HEILMAN, Philadelphia Iron Works, 412 N. Eighteenth St., Philadelphia.

NON-RESIDENT.

MR. EDWIN M. CHANCE, Philadelphia & Reading Coal and Iron Co., Pottsville, Pa.

Changes of Address.

MR. WHARTON BARKER, Port Royal Avenue, Roxborough, Philadelphia.

MR. WM. T. DONNELLY, 17 Battery Place, Room 930, New York City.

MR. BYRON E. ELDRED, 149 Broadway, New York City.

MR. PETER LOBBEN, 289 A St., Boston, Mass.

MR. ALFRED J. MAJOR, The Sedgley, Forty-fifth and Pine Sts., Philadelphia.

MR. JOHN E. NETHERY, 2025 W. Turner St., Philadelphia.

MR. W. M. WHITE, 375 Lake Drive, Wilwaukee, Wis.

NECROLOGY.

Mr. Charles Wallace Hunt, president of the C. W. Hunt Company and past president of the American Society of Mechanical Engineers and of the United Engineering Societies, died at his home, Staten Island, March 27, 1911.

Mr. Hunt was born at Candor, Tioga County, New York on October 13. 1841. He received his early education at Homer, New York, afterwards studying higher mathematics and mechanics under a private tutor. In the year of his majority he entered the military service of the Government. serving mostly in Virginia, from 1862 to 1865.

Upon his release from Government service about 1868, he engaged in mechanical pursuits and, after a few years of general experience, commenced the manufacture of machinery for handling materials on Staten Island. N. Y. in 1872. The result was the development of the now widely known plant of the C. W. Hunt Company, devoted to the production of a large variety of devices for saving labor in the handling of materials.

In addition to this large plant there were established plants in England and Germany for the manufacture of machinery designed by him.

He was deeply interested in the American Society of Mechanical Engineers of which he was elected one of the vice-presidents in 1892 and President in 1898. He was also a member of the American Institute of Electrical Engineers, The Franklin Institute and a number of other societies.

Mr. Spencer Meade.

LIBRARY NOTES.

Purchases.

The Library has recently acquired a valuable collection of some 40,000 printed abstracts of and references to, all the current electrical literature published in the electrical and numerous other scientific and engineering journals of this country and abroad, during the eleven years from 1893 to 1903 inclusive.

It is a complete collection of all the abstracts and references published in the *Digest of the Electrical World* during that period, during which it was compiled and edited by Mr. Carl Hering, it being the original collection made by the compiler for his own use.

Each abstract is on a separate card; the cards are classified into groups and sub-groups according to subject and date, and are contained in a cabinet of nine long double drawers of the usual style, thus making them very convenient for references and searches.

The years over which these abstracts extend include the periods of greatest development of many of the important branches of electrical science and engineering. In most cases the abstracts contain the substance of the original articles, papers or notes, together with the conclusions, occasionally accompanied by cuts, and the collection is therefore not a mere index of references, but contains in itself a very large amount of data and information.

Jahrbuch der Elektrochemie, 1906, part 1.

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BOOK NOTICES.

LES MACHINES A ECRIRE. Par Jean Rousset, Ingenieur Civil. 180 pages 7½ x 4¾ inches with 58 figures, paper. (Encyclopédie scientifique des Aide-Mémoire.) Gauthier-Villars, Paris 190. Price, paper 2 francs 50, cloth 3 francs.

Although the typewriting machine has been universally adopted, literature on the subject is apparently as meagre as the subject is of wide-spread interest. But few monographs containing analyses of these machines are

available and for explicit data search must be made through patent records and technical periodicals.

In this small volume, without attempting an exhaustive treatment, representative models are described and the mechanism employed in effecting their various functions are analyzed at considerable length, preceded by a most interesting outline of their origin and development. A particularly valuable feature, and one that should save much labor in investigating the state of the prior art, consists in the numerous references to original patents throughout the text, by the name of the inventor and year of patent. As is customary in the other volumes of the excellent series to which this monograph belongs a bibliography is appended. The completeness and extent of the data collected, despite the small compass into which it is condensed, are evidence that the subject has been elucidated by thoroughly competent hands and, as on previous occasions, the editors have shown rare discrimination both in their selection of subject and author.

GOOD ENGINEERING LITERATURE. What to Read and How to Write, With Suggestive Information on Allied Topics. By Harwood Frost, M. Am. Soc. M.E., M. Soc. Prom. Eng. Educ. Cloth, 420 pages 7½ x 5 inches. Price $1.00 net. Published by the Author. Distributing Sales Agents, Chicago Book Company, Chicago, 1911.

It is generally conceded that the quality of the literary productions of members of the engineering profession suffers by comparison with that of other professions. The necessity of rigid analytical method in the study of engineering problems tends often to discourage rather than stimulate what is commonly known as style. This and the often meagre inspiration to be derived from an engineer's environment may explain a considerably greater deficiency than is usually found. There is no royal road to the acquirement of a good literary style, and when one who is deficient in literary training is called upon in the course of his professional duties to express his thoughts in writing, precisely, clearly and in good form, there is no alternative but to devote the requisite time and effort to a study of the subject.

Although Mr. Frost's work is avowedly intended to lend a helping hand to engineers struggling with the difficulties of composition, only a slight attempt is made to give instruction on this subject and so may prove disappointing to many. The work will be found most useful to those who have mastered fundamentals and are called upon to perform editorial duties such as the preparation of manuscript for publication, the reproduction of illustrations, considerations of topography and other matters involved in the production of printed matter. A number of other topics of value incidental to editorial duties are included; among others, the relation between author and publisher, indexing and filing, literary criticism.

For the editor's office the book contains many valuable suggestions; for the literary novice, it serves to point out the difficulties which beset him and indicates where remedies may be sought.

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The Flight of Birds. By Giovanni A. Borelli. 40 pages, illustrations, plate, 12mo. Aeronautical Classics No. 6. London, Aeronautical Society of Great Britain, 1911. Price, in paper, one shilling net.

A Course of Qualitative Chemical Analysis of Inorganic Substances with Explanatory Notes. By Olin Freeman Tower, Hurlbut Professor of Chemistry in Adelbert College of Western Reserve University. Second edition, revised. 84 pages, 8vo. Philadelphia, P. Blakiston's Son & Co., 1911. Price, in cloth, $1.00.

Chemistry of Food and Nutrition. By Henry C. Sherman, Ph.D., Professor in Columbia University. 355 pages, 12mo. New York, The Macmillan Company, 1911. Price, in cloth, $1.50.

Traité d'analyses chimiques métallurgiques a l'usage des chimistes et manipulateurs de laboratoires d'acieries Thomas. Par J. Hognon, Ingenieur-chimiste diplome, 155 pages, illustrations, 8vo. Paris, Gauthier-Villars, 1911. Price, in cloth, 5 francs.

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U. S. Commissioner of Education. Report for the year ended June 30, 1910, vol. 2, 663-1373 pages, 8vo. Washington, Government, 1911.

CURRENT TOPICS

Radiation of Sound from Explosions. G. v. der Borne. (*Phys. Zeitschr.,* xi, 483.)—It has been observed that in the immediate vicinity of sources of sound of great intensity there is a region of *normal audible-distance,* then a zone about 100 kilometres wide where the sound is inaudible, followed by a very greatly extended region of *abnormal audible-distance,.* The explanation of this is that in the lower or foundation layers of the atmosphere in which the temperature falls as we ascend and the molecular weight of the air is practically constant, the sound rays are concave upwards. In the higher layers they are concave downwards and accordingly return, because in the higher regions of the atmosphere there is a larger proportion of the lighter gases, hence the molecular weight of the air is less, and the speed of sound greater. The wind has only a slight influence in these phenomena.

Chemical and Physical Effects of Pressure Uniform in All Directions. G. Spezia. (*Accad. Sci. Torino.,* Atti. xlv, 335.)— A mixture of finely divided copper and silver, maintained for one month under a uniform pressure of 8000 atmospheres, does not show the slightest sign of combination, and since the cupriferous deposits at Keveenaw Point contain copper and silver, which have been in intimate contact under pressure for a very long time, the author considers that Spring's theory that high pressure alone is sufficient to cause combination of these metals, is inaccurate. Experiments with wax, which Spring found to flow like water under a pressure of 700 atmospheres, show that no liquefaction or semi-liquefaction takes place with a uniform pressure of 9900 atmospheres for 12 days. The author criticizes the conclusions of Spring and Kahlbaum that increase of pressure causes a diminution in density of certain substances; the fact that copper used by Kahlbaum changed its shape on compression proves that the pressure was not uniform; for a wax prism, compressed in a water bath, maintained its shape after exposure to a uniform pressure of 3200 atmospheres for 24 hours.

First Roechling-Rodenhauser Furnace in the United States. Anon. (*Iron Age,* lxxxvi, 1439.)—An induction electric furnace, of this type will be installed by the Crucible Steel Casting Co., Lansdowne, Pa. It will be of 2 tons capacity, with a single-phase 25 cycle current, furnished by a generator driven by a 425-horsepower oil engine. Cold material will be charged for a time. later a cupola may be used for melting the scrap.

Petroleum Deposits on the Coast of the Gulf of Suez. (*Les Matières Grasses*, iv, 2129.)—It has long been known that petroleum deposits existed on the west coast of the Gulf of Suez, but they have been considered unimportant, as the borings at Jebel Zeit proved unsuccessful. Within the last two years fresh borings have been made in the peninsula of Jemsah, about 165 miles from Suez. At the depth of 1265 feet a fountain was struck, which threw up a column of oil 100 feet high. Analysis shows this oil contains a large proportion of petroleum spirit (benzine) and is free from water. Another well at Jemsah is yielding 600 tons per day (estimated). As these wells are near the coast, it is anticipated they will be worked in 1912. Reservoirs and refining works are being erected at Port Tewfik, near Suez. Experimental borings are being made at Jebel Zeit, in the islands of Gaysum and Taouila, and at Abou Zenima, which is only 60 nautical miles from the coast.

Influence of Lime on the Sulphur of Roasted Blendes. E. PROST. (*Bull. Soc. Chim. Belg.*, xxv, 103.)—Experimenting on the roasting of blendes, to which known proportions of lime were added, it was found in all cases that the more lime used the more sulphur was retained proportionately, and further additions to the charge of silica, lead oxide, or iron oxide had no appreciable effect on the decomposition of the calcium sulphate produced. Furnace trials confirm these laboratory results and indicate that nearly all the calcium present in the charge must appear as sulphate after roasting.

Influence of Nickel on Reactions. P. NEOGI AND B. B. AD-HICÁRY. (*Z. Anorg. Chem.*, lxix, 209.)—Ramsay and Young stated that small quantities of ammonia are formed when a mixture of nitrogen and hydrogen is led over red-hot iron, but the writers find there is no formation of ammonia from its elements in presence of either iron or nickel provided the nitrogen is free from nitric oxide. Pure nitrogen is most conveniently prepared by heating a mixture of ammonium chloride and sodium nitrite and removing most of the nitric oxide from the resulting gas by passing it through a solution of ferrous sulphate. Then dry the gas and remove the residue of nitric oxide by passing it over hot metallic copper. Nitric oxide is reduced to ammonia, sulphur dioxide to hydrogen sulphide and phosphorus pentoxide to hydrogen phosphide by hydrogen in the presence of reduced nickel. The reaction for nitric oxide begins at about 300°C. When nitric oxide alone is passed over reduced nickel, no production of a nitride, nitrite or nitrate of nickel was observed, hence it is concluded that the nitric oxide is reduced directly by the hydrogen, the nickel acting as a catalyzer. When sulphur dioxide acts alone on nickel some nickel sulphide is formed. When phosphorus pentoxide is heated with nickel in the absence of hydrogen, nickel phosphide and phosphate are formed.

Dielectric Strength of Oil. H. W. TOBEY. (*Electrician* lxvi, 491.)—This paper treats of the dielectric strength of mineral oil with regard to its use in electric power transmission apparatus. The voltage at which the oil breaks down varies greatly with circumstances, and a carefully chosen system of measurements is necessary, particularly in the shape of the terminals, which should be, preferably, brass discs facing each other horizontally. The dielectric strength does not vary greatly with temperature except when the oil solidifies, when it rises considerably. The most important factor is the presence of small quantities of water, which lower the dielectric strength. This water should be removed. Free sulphur lowers the dielectric strength, but its chief importance lies in its corrosive action on the copper conductors. A valuable test for sulphur is to dip a polished copper wire in the oil and note the rate at which it blackens. Insulation resistance is not an indication of dielectric strength unless temperature be considered, since it falls rapidly as the temperature rises, while the dielectric strength rises very slightly.

Luminous Tubes of Neon. GEO. CLAUDE. (*Mon. Scient.,* lxxiv, 135.)—The remarkable luminosity of neon can be utilized for lighting purposes. One of the difficulties of the problem is the ease with which neon is masked in luminous tubes by small quantities of certain other gases. It is not sufficient to introduce very pure neon into a tube with electrodes, under suitable pressure, in order to obtain an effective luminous tube, for the gases disengaged from the electrodes and from the walls by the current almost destroy its luminous power. This can be overcome by the use in a special way of Dewar's discovery of the absorbent properties of charcoal at low temperatures. In fact neon is not so easily liquified as the other gases introduced or set free by the passage of the current, and is therefore less easily absorbed than they are by charcoal at the temperature of liquid air. In this way neon is purified, and after prolonged treatment the beautiful orange luminescence appears and retains its brightness. This bright light is very rich in red rays and is just the corrective required for the light of vapor tubes : in many cases it could be used alone as for studios, halls and so forth.

New French Time. (Notes *Rev. Scient.,* xlix, 216.)—The new legal time is thus defined by law : " The legal time in France and Algeria is 9 minutes 21 seconds later than the mean time of Paris." This makes French time agree with the international time of Western Europe, *i.e.,* the time of the meridian of Greenwich. It also makes French time agree with the time adopted by the French railroads, which have previously adopted the international time.

Radio-Activity of Thorium. E. RUTHERFORD. (*Chem. News,* ciii, 22.)—The thorium emanation produces activity in substances exposed to it, and breaks up at the rate of 54 sec. for half disappearance, so that in 10 minutes practically none remains. There are four solid products of its disappearance. The first " Thorium A " is produced by the expulsion of an α particle, and decays to half-value in 10.6 hours, a slower decay than that of any of the other products, " Thorium B–C–D," the last of which emits both β and γ rays. The first of the transformation products of thorium itself is " Thorium X." It falls to half-value in 3.6 days. The next product is " Radio-thorium " which falls to half-value in two years. Then comes " Meso-thorium " with a half-value period of 5.5 years. This has almost the same properties as " Thorium X " and emits β and γ rays, and from it radio-thorium is formed, which emits α rays.

Fireclay Ware. C. SCHÄRTLER. (*Sprechsaal,* xliv, 17.— The manufacture of fireclay sanitary ware is meeting with some success in Germany. Slip-casting reduces the cost of manufacture by one-third, and enables pieces 4 inches thick to be cast. An engobe is introduced between body and glaze, and is applied by an ærograph, which is said to cost only one-twentieth of the cost of brushing it on. A convenient length for the tunnel-kiln is 330 ft. which holds about 80 trolleys laden with ware ; the journey through the kiln requiring 6 days. In charging the kiln with fuel avoid cold draughts, which are apt to crack the ware. The loss in manufacture should not exceed 10 per cent. from all sources. The goods nearest the fire are apt to get over-fired and the rest under-fired, owing to the obstruction of the flame by the ware.

Electrical Distribution in Massachusetts. ANON. (*Eng. Record,* lxiii, 178.)—Electricity was introduced into the State for illumination in 1880, both for streets and houses. This source of income proved unstable, so as a consequence there was soon a marked decrease in the number of generating stations relative to the areas supplied, and many of the companies underwent physical and legal consolidation. In 1888 there were 56 electric light companies, supplying 64 municipalities. At present there are 120 plants distributing electricity over 215 cities and towns.

Fluorescence and Band Spectra of Oxygen. W. STEUBING. (*Ann. de Physik.,* xxxiii, 553.)—A discussion and re-measurement of the fluorescence and band spectra of oxygen. He considers them in relation to Stark's theory of electrons and concludes that the negative band spectrum and the first band spectrum ($\lambda 3333$–$\lambda 2449$) are due to the atom of oxygen, while the second band spectrum ($\lambda 1919$–$\lambda 1831$) is due to the molecule of oxygen.

The Clinkering of Coal. L. S. MARKS. (*Eng. News,* lxiv. 623.)—After discussing the question of clinkering and the usual remedies, the investigation proceeds to discover the conditions under which the clinkering of a poor coal could be diminished. The results may be summarized as follows: The elements which cause clinkering are chiefly calcium, iron and sulphur. The exact amounts which may be present without causing trouble are not yet known with sufficient accuracy to permit the use of such a formula as Prost's with any security. In a general sense Prost's formula is correct, that is the fusion temperature rises as the alumina increases, and falls with the increase of the other elements, but it cannot be relied upon for any particular ash. The only real cure for clinkering is low temperature combustion. If the temperatures are high, clinkering can generally be reduced by the use of steam or by adding kaolin or quartz, but these are too expensive to be commercially justifiable.

Fusion of Carbon by Means of the Joule-effect. M. LA ROSA. (*N. Cimento,* xx, 302.)—A current of about 60 ampères at 150 volts was passed through carbon rods of 1, 2 and 3 mm. diameter, containing only 0.07–0.08 per cent. of mineral matter. If the full current is passed directly through the rod, explosion occurs, but by gradually raising the current by reducing the resistance, the carbon becomes luminous and bends slightly. By enclosing the carbon in a porcelain tube and then causing an explosion, stains are found on the sides of the tube, which under microscopical examination are apparently carbon. Though no complete liquefaction or crystallization of carbon has taken place, the results obtained are considered to indicate incipient fusion.

Color in Raw Rubber. D. SPENCE. (*India Rubber J.,* xli. 15.)—Spence does not agree with Kaye that the darkening of rubber is due entirely to enzymic action. The discoloration is probably due to the oxidation of polyhedric phenols, and it is emphasized that the velocity of oxidation depends not only on the enzymic activity, but also on the acid or alkaline reaction of the medium. The ease with which plantation Parà rubber can be obtained white is ascribed to the slight acidity of the medium.

Tellurides of Sodium and Silver. G. PELLINI AND E. QUERCIGH. (*Accad. Lincei,* xix, 350 and 415.)—By warming sodium and tellurium together in a quartz tube in an atmosphere of nitrogen, compounds of the formulæ Na_2Te, Na_3Te_2, and Na_3Te_7 were obtained. Thermo analysis of alloys of Ag and Te shows compounds of the formulæ $AgTe$ and Ag_2Te. The former is produced at 444° C., is decomposed at higher temperatures and polymerizes at 412° C.; the latter melts without decomposition at 959° C. and does not polymerize.

Persulphates and Per-Salts. F. J. G. BELTZER. (*Mon. Scient.*, lxxiv, 78.)—Persulphates can be prepared chemically by double decomposition between barium persulphate and sodium sulphate in saturated solutions. Barium sulphate is precipitated and filtered, and the sodium persulphate rapidly evaporated and crystallized; or barium persulphate is treated with its equivalent proportion of sulphuric acid, at very low temperaturre to prevent the decomposition of per-sulphuric acid. Electrolytically persulphuric acid is obtained by the action of the current on sulphuric acid at a low temperature. Alkaline persulphates are produced by the electrolysis of acid alkaline sulphates. Other conditions being equal, the relation between hydrogen peroxide and persulphuric acid is exactly defined by the relation between water and sulphuric acid. Finely divided platinum and silver decompose persulphuric acid catalytically with explosive violence; powdered zinc, magnesium and carbon decompose it quietly; powdered iron has no action. Wool and cellulose are instantly carbonized with a hissing noise; cotton is inflamed by a few drops in a few seconds. The formula for persulphuric acid is $H_2S_2O_8$. A modification, known as Caro's persulphuric acid, has the formula $H_2S_2O_9$. The persulphates are energetic oxidizers, and are used as decolorizers, as disinfectants, and as oxidizing agents in explosives. When neutral or alkaline solutions of chlorates are electrolyzed with a platinum anode and a platinized-platinum cathode, without a diaphragm, perchlorates are produced, but acid solutions require a diaphragm. Linen can be bleached by the available oxygen of per-borates which is set free at a temperature between 50° and 60° C.

The Properties of Aluminum Magnesium Alloys. WITOLD. BRONIEWSKI. (*Rev. Scient.*, xlix, 91.)—The electric conductivity and the thermo-electric force shown by alloys of aluminum and magnesium determine the existence of the two compounds, AlMg and $AlMg_2$ observed by Mons. Boudouard by means of the curve of initial solidification, and of the compound Al_2Mg_3 observed by Mons. Grube. The existence of the compounds Al_4Mg and Al_3Mg_2, has not been confirmed by the study of the electric properties.

Gageite, a New Mineral from Franklin, N. J. H. H. PHILLIPS. (*Am. J. Sci.*, xxx, 283.)—The specimens came from the Parker shaft and were associated with zincite. willemite, calcite and leucophenicite. The crystals are delicate, acicular, and hair-like, sometimes radiated and grouped in bundles protruding from the walls of small cavities. They are clear and colorless with a high vitreous lustre. Before the blowpipe gageite darkens to deep bronze or nearly black, but does not fuse. The crystals dissolve readily in dilute nitric acid. Their analysis is silica 24.71, manganese oxide 50.19, zinc oxide 8.76, magnesium oxide 11.91, and crystallized water 4.43 per cent.

Tantalum Lamps on Chicago Railway Cars. ANON. (*Electr. Rly. Journ.*, xxxvi, 1189.)—From an exhaustive series of tests, curves are given showing the fluctuations in voltage and current on the line circuit and particulars as to the way in which the durability and efficiency of the lamps were tested in actual operation. By the introduction of tantalum lamps a saving of not less than 5 cents per car-day, or $35,000 a year on the total cars of the company, was effected. Diagrams are given showing the period of renewal of the lamps, the miles run before replacement, etc., during different portions of the year. After extensive trials a variety of lamp was selected giving at 115 volts, 16 c.p. for 35 watts and 32 c.p. for 70 watts consumption. It is pointed out that in addition to the saving in energy consumption effected by the replacement of carbon lamps by tantalum lamps, the renewals per car-month are also less, viz., 2.21 as compared with 4.27.

Condensation of Radium Emanation. A. LABORDE. (*Le Radium,* vii, 294.)—If radium emanation be condensed at the temperature of liquid air, and the temperature be allowed to rise again, gas will begin to be evolved at about 20° C. lower temperature in a glass tube than in a metal tube. If a current of air carrying radium emanation be led at a constant velocity through a tube immersed in liquid oxygen 18 cm. long and 0.22 cm. diam. only 0.2–0.7 per cent. of the emanation escapes condensation if the tube be of metal (tin or copper), but 60–70 per cent. remains uncondensed if the tube be of glass. This does not seem to be due to the poor heat conductivity of the glass, for the condensation is greatly increased if a thin copper wire (0.024 cm. diameter) be placed inside it. If the glass tube be long enough it will condense nearly as well as a metal tube; 160 cm. of glass is about equivalent to 18 cm. of tin tube.

Colloidal Copper. A. RASSENFOSSE. (*Chem. Zentr.,* 82, 122.)—When anhydrous copper sulphate is dissolved in concentrated sulphuric acid, and alcohol added so as to form an upper layer, a violet zone, probably containing cuprous sulphate, is formed between the two liquids; the violet color gradually changes to brown owing to the production of a solution of colloidal copper. Methyl alcohol, ether, acetone, acetic acid and chloroform act in a similar way to ethyl alcohol. A solution of anhydrous copper phosphate in anhydrous phosphoric acid behaves in an analogous manner, on addition of an organic substance.

Life of Telegraph Poles. F. MOLL. (*Archiv. Post. Tele.,* xxiv, 673.)—After quoting many tables of figures the following conclusions are reached: Poles impregnated with zinc chloride have an average life of 12.1 years; with copper sulphate, 14.5 years; with corrosive sublimate, 16.5 years; and with creosote 22.2 years.

New Critical Point in Copper-Zinc Alloys. H. C. H. CAR-
PENTER AND C. A. EDWARDS. (*Inst. of Metals*, Jan. 1911.)—The
authors have detected pyrometrically, both in heating and cooling
curves, the thermal change at about 470° C. found by Roberts-
Austen in some copper-zinc alloys. It is not due to a eutectic.
The change is a true critical point and is found in all alloys contain-
ing from about 63 to 40 per cent. of copper. At 470° C., on cooling,
the so-called β constituent splits up into an intimate mixture of
α and γ. On heating, the reverse change takes place. Alloys
which just above 470° C. contain β are seen at a very high micro-
scopical magnification, when cooled below 470° C., to contain α
and γ. As γ is a very brittle constituent, the fact that the stable
phase above 470° C. is β, and below this temperature $\alpha + \gamma$ has
an important bearing on the cause of the brittleness and decay of
many brasses in engineering work. It also explains the " crystalli-
zation " of pure α alloys, as α consists of copper $+ \beta$. The brittle-
ness is entirely removed by annealing above 500° C.

A New Uranium Colloid. A. SAMSONOW. (*Zeit. Chem. Ind.
Kol.*, viii, 96.)—In attempting to prepare uranous chloride by the
electrolytic reduction of uranyl chloride, the author obtained besides
the dark green uranous chloride solution, a black precipitate soluable
in water. The solution of the black substance had the properties
of a solution of an electropositive colloid, which proved to be
uranous oxide, UO_2. It can also be obtained by the reduction of
uranous chloride with zinc or copper in weak hydrochloric acid
solution. Solutions of the colloid containing uranous chloride are
much more stable than those free from that substance.

Method of Treating Carbon Electrodes. Patented by W.
GASTON. (*U. S. Pat.* 979,465, 1910.)—The electrode is provided
with a " second binder " by saturating the hot, finished, carbon
electrode, immediately after it comes from the baking furnace, with
a boiling solution of a liquid hydrocarbon, such as pitch or tar.
The electrode is allowed to remain in the liquid until the cracks and
pores have become thoroughly impregnated. The liquid hydrocar-
bon is retained as such, and automatically prevents the cracking
of large carbon electrodes while in use.

Torgament Stone-wood Flooring. HENRY HESS. (*Amer.
Mach.*, xxxiv, 122.)—This flooring is a plastic mass spread over an
under floor of concrete. It is composed of Grecian cement
(magnesite), asbestos, talcum and sawdust, with a binder of chloro-
magnesium lye. The materials are carried to the place in powder,
mixed with the lye to a thick paste and then spread with a trowel.
Usually two applications are used, first a coarse, cheap composition
and afterwards a denser composition which can be colored to taste.
This torgament flooring is fire-proof.

On a Physical Interpretation of Non-Compensated Heat.
(*L. Decombe, Comptes rend.*, clii, 315.)—A large number of modifications or of material transformations are accompanied by electrical phenomena; such as chemical reactions, mechanical deformations, the thermic variations of crystals, etc. The deformation of a substance can, moreover, cause the effective electrification of the different elements of its mass, without producing any external electric manifestation; provided that the axes of the couples so excited are oriented simultaneously in every direction, without any one of them becoming preeminent. The absence of free electricity, or of sensible electrical phenomena, does not permit the conclusion that electrification is absent, and it can be conceived that such absence is rather exceptional. The electron theory of matter is obviously favorable to this conception. Every material modification inducing a variation of the electrical momentum of the atom may be considered as giving rise to electrification; any changes occurring without a variation in the electrical momentum are characterized, on the other hand, by the absence of electrification. [Here follow mathematical proofs of the statement.] Hence, under these conditions, we are led to compare non-compensated heat to Siemens' heat, both of which are essentially positive.

The Electrical Measurement of the Modifications Produced by the Exposure of Bi-chromated Gelatin. HANS MAYER. (*Rev. Scientifique,* xlix, 211.)—The following conclusions were reached experimentally: (1) Exposure decreases the electric conductivity of bichromated gelatin. (2) This conductivity is enormously diminished by a normal exposure. (3) The conductivity increases with the increase of temperature, and the coefficients of temperature differ according as the plates are sensitized or not. (4) The conductivity of the plate varies enormously with the atmospheric humidity; therefore this source of error must be eliminated to obtain true measurements. (5) The conductivity decreases in inverse proportion to the time of exposure, whatever the initial degree of conductivity of the plate may be. (6) The sensitiveness of bichromated gelatin (expressed in degrees of conductivity) decreases with time, as the plates age; rapidly at first, then slowly, and at last becomes stationary. (7) After the exposure is ended, the conductivity continues to decrease for a certain time in darkness.

Silundum, Aloxite and Alundum. ANON. (*Mont. Scient.,* lxxiv, 13.)—Silundum is a dense and compact form of carborundum, with a higher conductivity. It is used in electric heating apparatuses.

Aloxite is obtained by heating bauxite in the electric furnace. It is an artificial corundum.

Alundum is another form of aluminum oxide, fused in the electric furnace.

Use of Preservatives in Food. J. C. THRESH. (*Proc. Seventh Int. Congr. Appl. Chem.*, 211.)—It is contended that generally speaking, the use of food preservatives, in reasonable quantity, has not been proved to exert any injurious effect on health, and that in many cases the use of such preservatives is justifiable. Against the conclusions of Dr. H. W. Wiley, it is urged that in the experiments on which these conclusions are based, (1) the preservative was not, save in the case of formalin, administered with the food but in single daily doses, enclosed in capsules; (2) larger quantities were administered than would ever be taken in preserved foods; (3) the controls were insufficient and inadequate. The author refers to a U. S. Report according to which benzoic acid and benzoates, in the quantities used for food preservation, neither injure health nor impair the quality or nutritive value of foods. He considers that in some cases (*e.g.*, milk) the use of preservatives is neither necessary nor desirable and that if legislative action is necessary, it should be directed to preventing the use of preservatives in such cases.

The Bristol Recording Thermometer. ANON. (*Iron Age,* lxxxvii, 213.)—This is a gas filled instrument with an automatic compensating device. The new instrument, known as Class III, has been adapted to record lower ranges of temperature, than the instruments previously in use. The compensating device enables the instrument to give an accurate record of the temperature being measured, irrespective of any changes in temperature at the recording instrument itself. It consists of a special, spiral pressure tube, a capillary connecting tube and a sensitive bulb, the bulb and the connecting tube being filled with an inert gas under pressure. Temperature changes in the sensitive bulb produce corresponding changes in the pressure of the confined gas, and these changes are measured and recorded by the instrument. To make any error due to changes in temperature along the connecting tube negligible, the volume of gas in the sensitive bulb is very large in proportion to that in the capillary connecting tube.

Influence of Boric Acid in Diaminophenol Developers. R. NAMIAS. (*Proc. VII. Int. Congr. Appl. Chem.* ix, 11.)—Boric acid may be advantageously used as a preservative agent for diaminophenol developing solutions. When 50 Gm. per litre is present, the solution can be used after several months, and their reducing power is not impaired to the same extent as it would be by the use of bisulphites. The time necessary for development is only slightly greater than when boric acid is absent, and the quality of the images is unaffected. If potassium bromide is added to the solution, the rate of development greatly decreases, and the contrasts increase, so this is a convenient method for developing over exposed ·images.

Wiltshireite, a New Mineral. W. J. LEWIS. (*Phil. Mag.,* xx, 474.)—Found in a cavity in dolomite associated with sartorite at Binn (Valais). Its color is tin-white, and though its chemical composition could not be determined from the small quantity available, it is thought to be a lead sulpharsenite.

The Echelette Grating for the Infra-red. R. W. WOOD. —(*Physik Zeit.,* xi, 1109.)—The method of making a diffraction grating of rather large grating space, 1000 to 2000 lines per inch, is described. They were ruled with a carborundum crystal, by a Rowland's ruling engine, on a gold-plated copper plate. The groove was V-shaped, which concentrates a large proportion of the incident energy in a direction making an angle of approximately 40° with the direction of the incident energy. It is proposed to name such gratings " echelette."

The Electrical Conductivity of Commercial Copper. F. A. WOLFF AND J. H. DELLINGER. (Reprint 148 from *Bulletin of the Bureau of Standards,* vol. vii, No. 1. Washington, D. C.)—The investigation recorded in this paper was undertaken in view of the very considerable variation existing between the coefficients of conductivity, resistivity and temperature of commercial copper in use by various institutions in different countries. The samples upon which measurements were made were wires Nos. 6 to 18, B. & S. gauge most of them No. 12—and about 120 cm. in length, supplied by representative producers at home and abroad.

SUMMARY OF RESULTS

1. The various standard values in use for the resistivity and temperature coefficient of copper are given, and the need for the present investigation shown.

2. The means of making precise measurements of conductivity of wire samples is described.

3. The resistivities are given for 89 samples of commercial copper from 14 important refiners and wire manufacturers in this and other countries. The mean for annealed wires is:

Resistivity in ohms per metre-gramme at 20°C. 0.15292
Per cent. conductivity.............100.07 per cent.

(Per cent. conductivity is computed on the basis of 100 per cent. conductivity corresponding to the standard of resistivity, 0.153022 ohm per metre-gramme at 20°C.) The mean result of data furnished by a large wire manufacturing company, representing tests on more than 100,000,000 pounds of copper, is also given, viz., for annealed samples:

Resistivity in ohms per metre-gramme at 20°C. 0.15263
Per cent. conductivity.............100.25 per cent.

It is concluded that the best value to be assumed for the resistivity

of *annealed* copper, in the preparation of wire tables and in the expression of per cent. conductivity, etc., is the previously used . standard value, viz :

0.153022 ohm per metre-gramme at 20°C.

4. The conductivity of hard-drawn No. 12 B. & S. wires was found to be less than the conductivity of annealed wires by a mean value of 2.7 per cent. The difference between the conductivity of annealed and hard-drawn wires increases as the diameter of the wire decreases.

5. The lowest resistivity and highest conductivity found, for a *hard-drawn* wire, were :

Resistivity in ohms per metre-gramme at 20°C. 0.15386
Per cent. conductivity...............99.46 per cent.

and for *annealed* wire, were :

Resistivity in ohms per metre-gramme at 20°C. 0.15045
Per cent. conductivity...............101.71 per cent.

6. Representative mean values for commercial hard-drawn aluminum were obtained, as follows :

Resistivity in ohms per metre gramme at 20°C. 0.0763
Resistivity in micro-ohms per cm. cube at 20°C. 2.828
Density 2.70

7. The work on the temperature coefficient of resistance of copper, which is reported in another paper, was done upon samples included in this investigation. The temperature coefficient was found to be substantially proportional to the conductivity. This relation may be expressed thus : the change of *resistivity* per degree C. is a constant for copper, independent of the temperature of reference and independent of the sample of copper; this constant is

0.000598 ohm per metre-gramme.

8. The advantages of the expression of resistivity in ohms per metre-gramme are stated.

9. The desirability of an international standard of copper conductivity is urged.

Coke for Foundry Purposes. E. L. RHEAD. (*Eng.* xc, 107.) For foundry purposes coke should be (1) strong and hard, (2) dense, (3) of good cell structure, (4) as free as possible from ash. (5) should contain only a little sulphur, (6) should be uniform in texture. The best coke should not contain more than 0.7–0.8 per cent. of sulphur; if it contains more than 1.3 per cent. it is unsuitable for use in the cupola. High carbon coke with little ash and low sulphur, with suitable physical characteristics to enable rapid and complete burning in the smallest space, will insure the best results from the cupola by the rapid melting of clean, hot metal with the lowest possible fuel consumption. Coke should be kept dry under cover, for water introduced into the cupola means waste of heat. If the cupola is properly designed and the air supply properly regulated the coke cannot be too dry.

A New Mineral Water, and the New Physico-Chemical Methods of Examining Mineral Waters. ARMAND GAUTIER AND C. MOUREU. (*Comptes rendus,* clii, 546.)—In March 1909, a spring of mineral water, delivering 1870 litres per minute, was struck at a depth of 800 metres, in the Parc Sainte Marie at Nancy (France).

1. *Physical Examination.*—The color, limpidity, smell, taste, temperature, density, cryoscopic point, electrical conductivity, ionization and radio-activity were determined. In determining the electric conductivity, first the value K, given directly by the water, at 25° C., was ascertained, and then increasing volumes of distilled water of known conductivity were added to it, and the rate of the decrease in conductivity, consequent on the dilution was noted. Taking into account the mineralization of the water, and the conductivity of a solution of sodium chloride of approximately the same concentration, the degree of the ionization of the salts in this water was estimated at about nine-tenths.

For radio-activity, both the water itself, and the gases spontaneously disengaged (spontaneous gases) at the top of the ascending column of water, were examined by the Chéneveau and Laborde electroscope. The emanation of radium is expressed in milligramme-minutes in 10 litres of the gas and of the water. This was 0.46 in the spontaneous gases and 0.082 in the water. The radium as salts was estimated thus. The residue from the evaporation of a large quantity of water, after fusion with sodium carbonate, was redissolved in hydrochloric acid, raised to boiling to liberate the emanation, and left for several days in a closed vessel. The emanation thus accumulated was measured, and from this the quantity of radium in the water taken was calculated. Expressed as radium bromide there was found 0.012 mg. per 1000 cubic metres of water.

2. *Chemical Examination.*—There is nothing worthy of remark as concerns the reactions, the alkalinity, the dry residue and the sulphated residue.

Electro-positive elements, potassium, sodium, calcium, magnesium, iron and aluminum were determined by the well-known methods.

The following method was used for determining lithium. After concentrating 30 litres, the sulphates were precipitated by lead acetate, and the last traces by barium chloride. Calcium, barium, magnesium and ammoniacal salts were then separated, the dry mixture of alkaline chlorides was taken up three times by cold, concentrated hydrochloric acid, which dissolves all the lithium chloride and very little of the other chlorides; the hydrochloric extract was evaporated and treated with the *absolute alcohol amylic-ether* mixture, which dissolves the lithium chloride alone. The metal was finally precipitated as phosphate and weighed.

Traces of antimony and tin were found in the water, and the manganese was determined.

Electro-negative elements, sulphuric, hydro-sulphuric, phosphoric and carbonic acids, chlorine and silica were determined in the usual way.

Iodine was determined by the method described by one of us in *Comptes rendus,* cxxviii, p. 1069.

Bromine was determined by its liberation in a closed vessel, with the aid of heat, by chromic acid in presence of sulphuric acid; the liquid distilled, the distillate absorbed in a solution of potassium iodide; and the iodine liberated by the bromine titrated with hyposulphite.

Fluorine was determined by a hitherto unpublished method. After separating silica, calcium and magnesium the fluorine was precipitated as barium fluoride in alcoholic solution; the barium fluoride attacked by sulphuric acid, and the hydrofluoric acid set free determined as lead fluoride.

Boric acid was recognized by curcuma paper. Arsenic was determined by the method described in the *Bull. Soc. Chim.,* xxix, 859 by one of us.

Nitrates, nitrites, ammonium and organic matter. From the total nitrogen, determined by the Kjehldahl method, the ammoniacal nitrogen was deducted, thus determining organic nitrogen.

3. *Gases.*—(*a*) Spontaneous gases were determined over mercury. In 100 volumes of dry, natural gas, there were 1.75 volumes carbonic acid. and 98.25 volumes of a mixture of nitrogen, and the rarer gases, argon, krypton, xenon. helium and neon. These were recognized by their spectra. The 98.25 volumes of mixture contained 95.36 volumes of nitrogen, 1.29 volumes argon (with traces of krypton and xenon) and 1.60 volumes of helium (with traces of neon).

(*b*) Gases set free on boiling. Besides the ordinary gases. each litre of mineral water contained 0.45 c.c. of argon (with traces of krypton and xenon) and 0.19 c.c. of helium (with traces of neon).

Process for Rendering Celluloid Non-Inflammable. Patent by G. CHANDON DE BRIAILLES, No. 420,044, (French) 1909.—This process is particularly applicable to developed cinematograph films, celluloid in any form, and artificial silk. It consists of de-nitration under conditions which prevent shrinkage and deformation. The operation is conducted in a digester by the action of a solution of ammonium sulphide, ammonia and gelatin of suitable concentration and temperature. The liquid is forced into the material under a pressure of 10 atmospheres. developed by hydrogen sulphide gas. The strips of films are wound in a spiral on a plate carrying metal pegs surrounded by glass tubes. which hold the films apart. The camphor and nitro derivatives removed by the treatment are replaced by the gelatin, and thus shrinkage is prevented. The gelatin is subsequently rendered insoluble. Artificial silk is subjected to an after-treatment with boric acid.

A New Effect of Light. W. SCHEFFER. (*Brit. J. Phot.*, lvii, 705.)—The emulsion from ordinary films was softened in water, melted, diluted with water and examined under a microscope with strong illumination. When first exposed the halide grains show a motion like that of the Brownian movement, but after a few minutes' exposure this motion ceases, the grains disappear, and only larger, black, granular aggregates remain, resembling those produced by ordinary development.

A New Electric Furnace for Steel Melting and Refining. JOH. HARDÉN. E. E. (*Met. Chem. Eng.*, ix, 38.)—A combination arc and resistance furnace worked like an open-hearth furnace, which is adapted for crucible steel work, and for the highest grade tool steel. The slag-blanket is kept hot by arcs across the slag, while terminal plates transmit the necessary heat to the bath. For de-phosphorization and de-sulphurization any desired temperature may be attained without superheating the surface through the ter- minal plates. Controlling devices secure any desired gradient of heat. The threefold advantages of this type are ; (*a*) the size of the electrodes is only about one-half that of an arc furnace of same capacity ; (*b*) the maintenance cost is less, due to the two sources of heat and the smaller electrodes ; (*c*) there is better control of the load factor of the furnace, because the current from the resistance plates is steady, and compensates for the large fluctuating arc currents. This furnace is economical because of low power consumption, standard electrical apparatus, and simple control.

Adjustment of Tension Members in Bridges. ANON. (*Eng. Record*, lxiii, 242.—Tension members which have become bent or slack have been straightened and shortened so as to take their proper share of the stress, by the thermit process. As described in the *Zentralblatt der Bäuverwaltung* the work is done without inter- rupting the traffic. Two clamps are attached to the tie, one above and one below the point where the shortening is to be done, and the clamps connected by two bolts. A two part mold is placed around the tie, the mold charged and ignited. The tie soon becomes white hot and the bolts are then drawn up to the desired degree. Tests made at the Royal Testing Laboratory, at Gross Lichterfelde, indicate that the metal is little impaired in strength by the thermit application.

Titanium Thermit. ANON. (*Mon. Scient.*, *Mercure*, v, 21.)— This is an intimate mixture of aluminum and rutile (titanium dioxide). On igniting this mixture, a very high temperature is attained, with the production of ferro-titanium and alumina. It is advantageously used for purifying castings and converting them into titanium steels.

The Chemical Properties of Radium and Its Compounds.
M. FORCRAND. (*Mon. Scient.*, v, 201.)—The little that is known
of radium and its compounds fixes its position, as Curie did at
first, in the barium series, as the heaviest of the alkaline-earths,
with the atomic weight of 226.5. Its bromide is isomorphous with
barium bromide, and both nitrates are equally soluble; radium
chloride is a little less soluble in alcohol and in hydrochloric acid
than barium chloride, and the carbonate a little less stable than
barium carbonate. Madame Curie and M. Debierne have lately
shown that the metal can be obtained by a process similar to that
by which Guntz prepared barium; that it melts at 700°C., and
forms a nitride which decomposes water in the cold, giving a
soluble base. These facts fix the position of radium, between
barium and sodium. The decomposition of water, in great excess,
by metallic radium disengages between $+ 46.25$ ($\frac{Ba}{2}$) cal. and
44.1 ($\frac{Na}{2}$) cal., *i.e.* about $+ 45$ cal. for $\frac{Ra}{2}$ with disengagement of
hydrogen in the cold; and the formation of an oxide a little more
soluble than BaO and a little less soluble than Na_2O. This oxide,
combining with water, forms a strong base $Ra(OH)_2$, which is
a little more stable than $Ba(OH)_2$ and dissociates more easily
than $NaOH$. The anhydrous oxide RaO is easily peroxidized at
red heat to a fairly stable binoxide RaO_2; the heat of formation
of which is about 19 cal. It combines with CO_2 to form a carbonate
with the disengagement of about 70 cal. partially decomposed at
bright redness. It is probable that the metal would combine directly
with hydrogen to form the hydride RaH_2 with 17.6 cal.; reacting
on water in the cold with the disengagement of hydrogen.

The Heroult Furnace in Germany. (Correspondent of *Iron
Age,* lxxvi, 1430.)—The Lindenberg Co., of Remscheid, which
holds the German patents for the Héroult electric furnace states
in its annual report that this furnace is making steady progress in
Germany. There are 23 furnaces now in operation and 17 in
course of construction, three of them of 20 tons capacity. The
23 furnaces in operation produce 225,000 tons of steel a year. The
Company claims to have worked out new metallurgical processes
of far-reaching importance, and has applied for patents on them
in all important countries.

Machine Blowing of Window Glass. E. JUSTUS MILLER.
(*Amer. Mach.,* xxxiv, 403.)—The old hand process of making
glass is now superseded by modern machines. The molten glass is
placed in white hot clay pots and drawn and blown into cylinders
thirty feet long, by hydraulically operated air blowpipes. These
cylinders are slit, then flattened into sheets. It requires extreme
care to produce clear glass. An interesting and instructive paper.

Monel Metal. J. F. THOMPSON. (*Eng. and Min. J.,* xci, 223.) —This alloy is made from the nickel-copper ores of Ontario and contains about 68 per cent. of nickel and a little iron. It is nearly as strong as steel and is as non-corrosive as copper or brass. The rolled metal is used for roof covering, screens and mining pump-rods. Large castings of monel metal are used for the propellers of turbine-driven ships. After a year's service this proved so satisfactory that the U. S. Government now specify this metal for propellers. Other navies use this metal. The cast metal has a tensile strength of 82,500 pounds per square inch, an elastic limit of 37,500 pounds per square inch and elongation 4.4 per cent. The modulus of elasticity is from 22,000,000 to 23,000,000 pounds as compared with 30,000,000 pounds for steel and 13,000,000 for manganese bronze. Castings can be produced up to 30,000 pounds weight in one piece. Its melting point is 1360°C., its specific gravity 8.87 (cast) ; electrical conductivity is 4 (copper 100) ; shrinkage ¼ in. per foot ; hardness (cast) 22, (rolled) 27 by the Shore sclero-scope. It retains its mechanical properties at a high temperature. At 1000°F. monel metal retains 80 per cent. of its tensile strength and elastic limit, while steel only retains 71 per cent. and manganese bronze only 60 per cent., while copper loses 60 per cent. at 780°F. This property led to its adoption for locomotive fire boxes in Germany.

The Chemist in the Brass Foundry. C. E. OTT. (*The Metal Ind.,* viii, 501.)—The chemist should be in absolute control of weighing, mixing and melting, for slight variations in weight often lead to faulty castings and other gross errors. He must have an accurate knowledge of the alloying properties of different metals and be able to produce alloys for any desired purpose. He must know what impurities are allowable and their percentages, and he must know how to eliminate these impurities if such a thing is possible. He must be acquainted with fluxes, their melting points and other physical properties. It is his duty to determine accurately, with the pyrometer, the temperature best suited for the pouring of the melt and then to make charts giving the weights of the various metals in an alloy and the temperature at which it should be poured.

Utilization of Wave Energy. ANON. (*Amer. Mach.,* xxxiv, 227.)—An Italian engineer, who is the inventor of a new sea motor for which great claims are made, states that the reason why the energy of waves has never been utilized is because it has never been recognized that they have a double force ; one derived from the height of the waves' crests above the water level, and the other from the body of the waves as they roll in upon the shore. His invention utilizes both forces. It is reported that an investigation of the invention by the Italian Admiralty had favorable results.

A New Type of Electric Furnace.—*Abstract.* At the recent meeting of the American Electrochemical Society in New York, Mr. Carl Hering described a new electromagnetic phenomenon which he has named the " squirt phenomenon " and which he is using as the basis of a new type of electric furnace, for which he claims it is particularly well adapted.

This new phenomenon is as follows: If an electric current is passed lengthwise through a liquid conductor, like a molten metal which is confined in a tube or hole closed at the bottom by the electrode, and opening at the top into a bath of the molten material— then the liquid in the hole will be squirted out axially quite forcibly through the central part of the open end, and other liquid will be forcibly sucked down into the hole around its periphery, provided the relation of the current to the cross section of the liquid conductor is sufficiently great. It may be said to be a valveless pump circulating the liquid rapidly throughout the hole.

If this hole is located in the bottom of a crucible or hearth and is so proportioned that the current will produce the necessary heat in the material in it, by virtue of its electrical resistance, the device will constitute a new kind of furnace, in which the liquid in the hole constitutes the resistor; it may be said to be a furnace with a " flowing resistor." The cooler liquid material flows down into this hole near the circumference, becomes heated by the current and is then at once expelled with considerable force to the top of the bath, where, in the case of the refining of steel, it comes into direct and intimate contact with the blanket of slag which takes up the impurities mechanically and chemically. In the furnace there are, of course, two such flowing resistors, one for each electrode.

The chief claims made for furnaces based on this principle are: greater heat economy, as the heat is all generated directly where it is wanted, without waste; much greater rapidity of refining, when the furnace is intended for steel refining, on account of the enormous and continually changing surface exposed to slag action; hence greater furnace capacity per day and greater heat economy, due to the shorter time of treatment; great homogeneity of the product due to the very rapid circulation; cheapness of construction, as the furnace consists merely of two holes in the bottom of a hearth, plugged with the two electrodes; no unnecessarily high temperatures with their attending heat losses; no consumption of electrodes with its attending costs; ease and nicety of regulation; no machinery for regulating an arc; applicability also to zinc and arsenic ores, glass, etc.; adaptability to being added to existing open-hearth furnaces or pots; possibility of adding fuel heat at the top of the lower temperatures; an arc may be added if desired; etc.

The force which produces this squirting action is caused by the so-called " pinch effect," described by the author some years ago, which is a radial force tending to contract the cross section of a conductor as though it were being pinched or squeezed; in the squirting phenomenon this radial force is made use of to produce

a pressure at the centre and a suction at the circumference, which in turn produce the upward and downward flows of the liquid. The forces were found to be surprisingly great, hence the heating may be made to be very rapid, as the heated liquids are expelled very quickly, the particles of the material being in the hole only a moment, probably not more than a second or two. Trial furnaces have operated very successfully.

Preserving Timber. ANON. (*Eng. Record,* lxiii, 310.)—The penetration of timber preservatives to be expected from the amounts of preservative usually specified are given by Mr. R. L. Allardyce, superintendent of the International Creosoting and Construction Co., of Texarkana, Tex., as the results of his experience. The figures refer to Southern pines treated by the full cell method. Bearing in mind the many variations in conditions, a fair average, based on numerous borings is given as $\frac{3}{4}$ to $1\frac{1}{2}$ inches, in soft or sap wood for a 10 to 12 pound treatment on piling, using dead oil of coal tar; $1\frac{1}{2}$ to $2\frac{1}{2}$ or 3 inches for a 14 to 16 pound treatment; $3\frac{1}{2}$ to 4 inches for a 20 pound treatment and $4\frac{1}{2}$ inches to complete penetration for 22 to 24 pounds. In heart wood the penetration is less. In a straight zinc or Burnettized treatment of loblolly ties, a 20 pound treatment of a light solution is given for complete penetration, or up to the last 1 or $1\frac{1}{2}$ inches from the centre. For short leaf or long leaf pine ties a stronger solution is recommended and never less than 100 pounds per square inch pressure during treatment.

Protection of Tools from Corrosion. ANON. (*Amer. Mach.,* xxxiv, 193.)—Tools can be kept clean and bright by coating them with mercurial ointment, known as "blue butter," which resists moisture. It should be handled carefully as it is somewhat poisonous. Another good resistent is made by heating 6 parts of lard with 1 part of rosin till the rosin is melted. Remove mixture from the fire to a safe place and add about 1 pint of benzine to each half-pound of the lard-rosin mixture. When cool, rub the mixture over bright steel articles. Tools treated in this way will resist the corrosion of even salt water.

Nitrification by the Ultra-violet Rays. D. BERTHELOT AND H. GAUDECHON. (*Rev. Scient.,* xlix, 314.)—The nitrification of aqueous solutions of ammonia, or of ammoniacal salts, or of nitrogenous organic bodies, can be caused by the ultra-violet rays in the presence of oxygen gas. The oxidation ceases at the nitrous stage, and inversely nitrates are reduced to nitrites. In concentrated solutions the reduction is carried still further, and as a particular case, ammonium nitrate disengages pure nitrogen gas. The ultra-violet rays act as ferments; and according to circumstances, cause a gain or loss of combined nitrogen.

The Combustion of Gaseous Fuel. (*J. Gas Lighting*, cxii, 711.)—An English patent has been applied for by Bone, Wilson and McCourt for an apparatus for burning an explosive mixture of two or more gases or vapors, so as to obtain complete combustion and to utilize the heat generated to the best advantage. This apparatus consists of a permeable diaphragm or refractory material in conjunction with a chamber or casing, the diaphragm forming one wall of the chamber, into which the gaseous mixture is led through pipes. The mixture passes through the diaphragm and is ignited at or near its outer surface. This apparatus attains very high heats by utilizing the accelerative influence of incandescent solids on gaseous combustion. The solids consist of (1) an outer shell of refractory material and a bad conductor of heat; (2) an inner bed of refractory material having interstock, into which bed the gaseous mixture is introduced and in which it burns; (3) an internal chamber, in which the heat generated is utilized; (4) a passage through which the carburetted gaseous mixture passes, of such dimensions in relation to the gas flow that the ignition of the combustible mixture shall not travel backward in the passage.— (Eng. Pat., 29430, Dec. 16, 1909.)

Purification of Boiler Feed Water Without Chemicals. ANON. (*Iron Age,* lxxxvii, 533.)—(A paper discussed by the Soc'y. of Chem. Industry, N. Y.) Mr. Thos. R. Duggan, of London, Eng., read a paper on the purification of boiler feed water, calling attention to the cost of chemical purification and the disadvantage of using chemicals in water to be used for brewing or dyeing. This led to the consideration of Herr Brandes' device for the softening of old scale and the formation of less new scale, known as the aluminator. The boiler feed water is run over an aluminum plate, at a certain slope and of various widths and corrugations according to the condition of the water. The theory is that a current of electricity is induced by the flow of water over the aluminum plate and the salts in the water are thereby ionized. The plate should be fixed in a north and south direction and exposed to the air. The advantages claimed are the prevention of hard scale, automatic action, absence of all chemicals, the metal of the boiler is unaffected, corrosion and pitting are avoided, fuel is economized, and free steaming obtained, at a very low cost.

Distinction Between Gutta and Rubber. G. HÜBENER. (*Gummi-Zeit.*, xxv, 634.)—Gutta and rubber behave differently towards chemical reagents. Ozone attacks solid rubber, but not solid gutta-percha. Rubber is easily vulcanized by sulphur, gutta is not; the affinity of gutta-percha for oxygen is much greater than that of rubber. Caspari's gutta-percha bromide is represented by the formula $C_{30}H_{46}Br_{10}$ and on heating to 130° C. is decomposed with evolution of hydrogen bromide.

Electrical Smelting of Iron Ore, Copper, etc., in Norway. (*Board of Trade J.,* Feb. 23, 1911.)—The Stavanger Electro-Staalverk Association with a capital of about $125,000, has been formed for the electrical production of high-grade steel from scrap iron and steel. Works will be erected at Jörpeland, near Stavanger, where a supply of 2500 h. p. of electrical energy has been secured, and this supply can be increased to 10,000 h. p. It is estimated that the annual output will be 1400 tons of high-grade steel billets, 600 tons of cast steel, 300 tons of hammered steel and 700 tons of scrap for re-smelting. The directors of the Tinfos paper mills have turned over the electric iron ore smelting concern at Notodden to the "Tinfos Jernverk, Asso." with a capital of about $275,000. The "Ass. Arendals Fossekompagni" has been established for iron smelting, under the management of Mr. Eyde. It is said to own the Böilo Foss waterfall, near Arendal, which can produce 30,000 h.p. of electrical energy, though only 12,000 h. p. will be harnessed to commence with. The Ilen smelting works of Trondhjem will begin the electrical smelting of metals using the process invented by their works director, Mr. Tharaldsen, starting with a 1000 h. p. furnace for copper smelting, estimated to produce 2000 tons per annum. A second furnace capable of producing 9000 tons per annum is expected to start in the spring. A consignment of 25 metric tons of pure, electrically smelted copper has been exported from the Birtavarra mines, at Kaafjord, near Lyngör. The "Kristianssands Nikkelraffineringsverk," Christianssand, is about to start the electrical smelting and refining of nickel and copper.

A New Arc Lamp. E. URBAIN, C. SCAL, AND A. FEIGE. (*Comptes rend.,* clii, 255.)—By striking an arc between a tungsten anode and a mercury cathode, 5 m.m. apart, in a vacuum or an inert gas, a very bright light is obtained similar to sunlight and very rich in ultra-violet rays. The spectrum is continuous with the mercury lines superposed. In vacuo the potential difference is 12 volts, but in the presence of an inert gas this can be greatly increased. The efficiency is about 0.45 watt per candlepower. The arc has a very high temperature which explains the necessity of using the very refractory metal tungsten as the anode.

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